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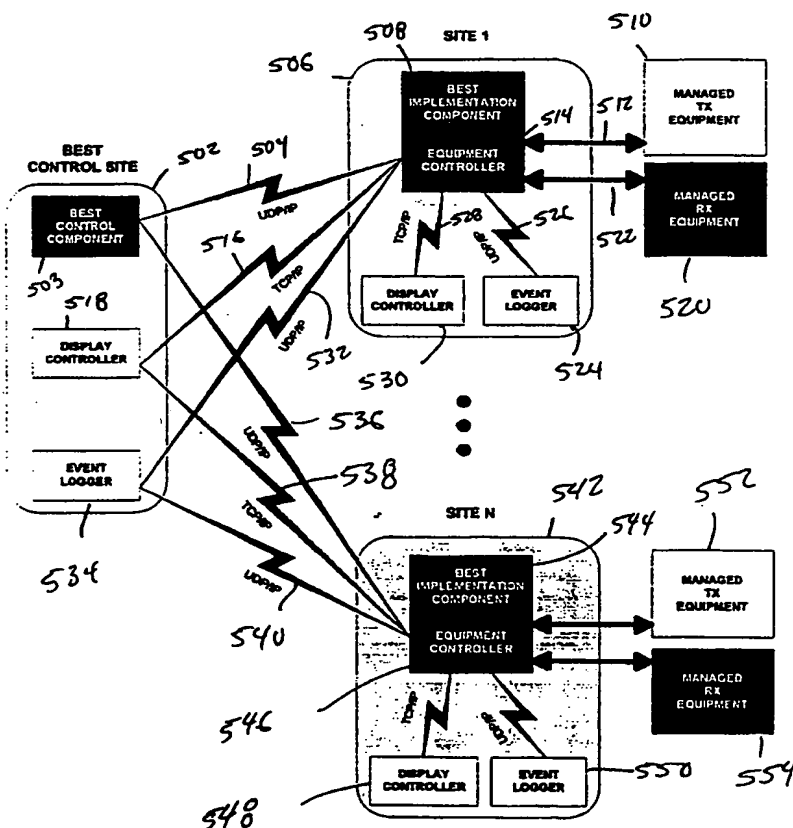
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(54) Title: CAPACITY ALLOCATION SYSTEM USING SEMI-AUTONOMOUS NETWORK ELEMENTS TO IMPLEMENT AND CONTROL A TRANSMISSION SCHEDULE

(57) Abstract

A system for controlling a network of communication terminals (510, 520, 552, 554) with a management component (503) and an implementation component (508, 544), said implementation component (508, 544) in communication with said management component (503) to receive at least one transmission plan, said transmission plan containing a scheduled implementation time, said implementation component (508, 544) receiving said transmission plan, decoding an implementation time for said transmission plan and outputting command to network component at said implementation time to implement said transmission plan.



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**CAPACITY ALLOCATION SYSTEM USING
SEMI-AUTONOMOUS NETWORK ELEMENTS TO
IMPLEMENT AND CONTROL A TRANSMISSION SCHEDULE**

FIELD OF THE INVENTION

This invention relates to communication methods and apparatus for providing network management, bandwidth and path control in a heterogeneous network that may be composed of multiple vendor equipment and transmission paths. More specifically, the communication system concerns semi-autonomous implementation components within a management hierarchy to globally manage multiple vendor elements while satisfying local network demands.

BACKGROUND OF THE INVENTION

Telecommunications services have, for many years, attempted to optimize or minimize bandwidth usage between network elements. Since the modern communications era, brought about by the theories of Shannon, telecommunications engineers have been keenly aware of the need to provide optimal, or at least good solutions, to bandwidth allocation problems in point-to-point and point-to-multipoint networks.

In wireless communication systems, solutions to bandwidth allocation problems can be seen in the way data is modulated to "share" finite resources. For example, time division multiple access ("TDMA") provides a means for multiple stations to access time slots on satellite carriers and thereby "share" bandwidth resources. Code Division Multiple Access ("CDMA") provides a means to use code division modulation techniques (time and frequency modulation) for multiple point access to a predetermined range of bandwidth and thereby "share" bandwidth space. Likewise, frequency division multi-access ("FDMA") provides a means to divide up and share a finite bandwidth resource.

More elaborate schemes to dedicate bandwidth in accordance with a predetermined transmission schedule and modulation plan can be seen in U.S. Patent No. 5,592,470 to Rudrapatna *et al.*, ("Rudrapatna") issued January 7, 1997, (the "Rudrapatna patent"). The Rudrapatna patent concerns a terrestrial micro-port network that allocates bandwidth to
5 terrestrial micro-port receivers based on a pre-determined schedule and modulation plan. The pre-determined schedule and plan may be subsequently modified by dynamic demands on the micro-ports. The network can then satisfy the dynamic demands by moving channels between modulation and polarity schemes in pre-determined amounts.

In wireless networks, certain communications links require more bandwidth and
10 power resources than others. This is necessary to maintain specified information throughput, to provide appropriate grades of service or due to varying site configurations (*e.g.*, different antenna sizes). Whenever a change in network resource allocations is required to match varying traffic requirements, a new transmission plan may or may not be implemented. This may necessitate programming, transmitting and receiving communications equipment, *e.g.*,
15 amplifiers, modulators and demodulators, to support the new resource assignments. These and other problems in bandwidth allocation in a multi-vendor network are addressed by the present invention.

SUMMARY OF THE INVENTION

The methods and apparatus disclosed herein may assign and re-assign available
20 transmission resources in point-to-point, multipoint and broadcast wireless networks. This may be accomplished on the basis of information capacity and connectivity requirements between transmitters and receivers of communications links at the time of assignment or re-assignment. The system may also provide a network administrator with novel tools and automated methods to define and implement network transmission plans and to modify
25 allocation decisions as traffic requirements change.

The system may provide the tools to efficiently allocate transmission resources. These tools help implement the communications links that form wireless networks. An optimum resource or a "good fit" allocation is achieved when network users have just enough information transmission capacity to perform their tasks. One way to accomplish optimal or good transmission resource allocations in a wireless network is to analyze network users' usage patterns and allocate capacity according to a time-varying schedule.

By analyzing network usage patterns, a management component can determine a transmission plan schedule that efficiently allocates the satellite bandwidth available to the network based on historical usage patterns. The management component may automatically schedule and implement a transmission plan. As the network users' requirements change, the management component may update or modify the scheduled transmission plans to satisfy the new requirements.

The system may automate implementation of transmission plans by reprogramming the system when predetermined parameters are reached. For example, the management component may determine a transmission plan from a historical analysis of bandwidth requirements between stations. This transmission plan may be automatically deployed to the network. The management component can then monitor and analyze network allocation demands to determine a new transmission plan. The new transmission plan can then be automatically deployed in the network when predetermined parameters are reached, such as, average change in bandwidth, *e.g.*, bandwidth in use/bandwidth in the transmission plan, exceeds a predetermined amount or if a predetermined amount of time has transpired. The transmission plans may be propagated as generic network commands and translated into corresponding equipment parameters and associated control commands as required for reconfiguring network equipment elements. Thus, the system may generate and distribute

equipment configurations to network elements to reprogram for synchronized execution at predetermined times.

The system further controls and schedules bandwidth between network elements to consider other network factors such as economic constraints. In a wireless communications network, each communications carrier should have just enough bandwidth and power necessary to meet the needs of its corresponding users. Although optimum resource allocation is the primary goal, sub-optimum allocation may be tolerated when economic constraints may limit transmission resources to finite amounts. Thus, for example, a dynamic bandwidth requirement at a network station may require an increase in bandwidth allocation from the station, such as when the queuing depth reaches a predetermined amount at the station switch. The station may have additional capacity available on an available communication link, however, the incremental capacity of the link may far exceed the bandwidth required to reduce the depth of the communication queue. Furthermore, the financial cost of the incremental capacity may exceed the cost of waiting for network usage to decrease to reduce the depth of the queue. The system, in this case, would allow the network to back up and flow control the user data before the system would allocate additional capacity. The system provides methods to use finite transmission resources by enabling power and bandwidth to be re-allocated as needed to meet changing communications requirements in satellite networks. However, the capabilities of the system are applicable to all wireless networks that can be modeled as a collection of transmitters, transmission resources, and receivers.

The system provides a means to manage heterogeneous or multiple vendor network equipment over heterogeneous or multiple vendor transmission resources with multiple transmission paths. One such path may be via programmable C-, Ku-, or Ka- band satellite networks. Other paths may be via discrete carriers available on a preprogrammed networks

such as the Inmarsat, Globalstar or Iridium satellite systems. Yet other paths may be via third party medium or broadband networks such as the envisioned Teledesic satellite network. Yet another path may be over a programmable or managed network such as the Intelsat global satellite system. Thus, the system provides a means to define and manage capacity between
5 network elements where the network may be a combination of a discrete bandwidth allocation network managed by an external system, a semi-programmable medium or broadband network wherein a varying amount of bandwidth may be allocated from an externally managed resource and a fully-programmable network where the resource is managed by a network management component. Thus, the management system provides a nearly
10 transparent means by which an operator, user or network element may place demands on the network and the management system may satisfy those demands based on a least cost algorithm, quality of service parameters and pre-defined or time-varying transmission plans.

The management system described may configure the transmission elements (transmitters and receivers) in a wireless network to implement a specified allocation of
15 transmission resources according to varying, scheduled or ad-hoc capacity requirements. The system maintains a schedule of transmission plan implementations and may automatically perform each implementation at a scheduled time.

The semi-autonomous network management system essentially consists of two semi-autonomous components. The first component is the Implementation Component (IC) which
20 executes at a site containing network transmission elements and the second is a Management Component (MC) which executes at a network management site. These components may be connected via a user datagram Internet protocol messaging format.

At the heart of the system is the IC. The IC may be a stand-alone application program that controls one or more network elements. A network element may be the station or
25 communication equipment physically controlled by an IC. Thus, it is usually the case that the

network element is a stationary or mobile communications node at a single physical location. The IC may, however, remotely control a network element.

In one embodiment of the present invention, the IC application may execute in a dedicated processing environment such as a PC executing UNIX or other suitable operating system such as Windows or DOS. The IC may also execute on an integrated or embedded processor such as a PC on a card environment with an application specific or real time operating system executing thereon .

The IC is semi-autonomous, *e.g.*, it can translate allocation commands from a management component into executable commands for its associated network elements without having direct, full-time contact with the network management component. The IC may store pre-programmed parameters, transmission plans, or collection commands for automatic execution. The IC may map a network programming language command set or generic allocation command to a vendor specific command sequence. The IC may contact the management component to receive permission to access network bandwidth, to report the unavailability of network elements, or to request different allocation parameters if or when local demands exceed the IC's preprogrammed allocations. Thus, the IC may provide independent control over network elements while maintaining or executing a management plan.

In the semi-autonomous network management scheme disclosed, transmission schedules may be loaded in advance of the implementation of the scheduled transmission plans. Then, at a predetermined time, the network can switch over to the new transmission plan to implement the optimal, or at least good solution, before more complicated dynamic bandwidth allocation algorithms would need to be employed.

In addition to automatically implementing scheduled transmission plans generated by the management component, the system may also perform network usage analysis.

Automated network usage analysis may require that the management component have access to traffic data collected for the network. The data may be collected automatically or manually by the management component or the implementation component may interact with the elements in the network to collect the usage data. The management component may use
5 statistical methods to analyze the gathered network usage data to suggest or implement optimize transmission plans for efficient use of the available resources according to a schedule.

Efficient use of bandwidth spectrum may be achieved on various levels in the system. On a first level, bandwidth may be scheduled in accordance with a historical analysis of
10 demands on the network. For example, it may be determined that Monday morning traffic is mostly outbound (*i.e.*, from a central earth station to a mobile station). On Fridays, however, most of the traffic is in the opposite direction (*i.e.*, from mobile stations back to the central earth station). In this instance, an assymetric channel may be opened for Monday traffic to provide higher outbound data and a slower speed return path. Then the opposite allocation
15 may be established for Friday's traffic (*e.g.*, a high speed channel from a mobile station to the central station and a low speed acknowledgment channel from the central station back to the mobile station). This may provide an optimal, or at least a cost-effective solution for the capacity requirements at a particular time.

On a second level, the system may allocate capacity based on class of service
20 parameters available, for example, through an Asynchronous Transfer Mode ("ATM") type packet format. For example, a class of service may identify data packets with low priority for a particular application. In such a case, an expensive satellite carrier may not be necessary and a lower-cost transmission resource may be put online by the network to pass the required data packets. Thus, the present network can mix class of service bandwidth allocation

methods with least cost routing decisions based on predetermined parameters programmed in the IC.

The semi-autonomous nature of the network management components may use a datagram protocol for interprocess communication. More specifically, the network components may communicate through the use of the User Datagram Protocol ("UDP") over an internet protocol ("IP"). Communication between the management component and the IC may use a polled or interrupt methodology.

In a polled mode, the management component contacts each of the ICs to pass UDP/IP messages or to receive Transmission Control Protocol/Internet Protocol ("TCP/IP") information from the particular IC. In an interrupt driven mode, the IC may attempt to communicate with the management component. The interrupt mode may be used to re-establish contact with the MC if the IC loses synchronization with the network or to pass alarm or other local conditions happening at the IC that may not be detected by the management component. In the interrupt driven mode, the IC may have a preassigned back-up channel or predetermined bandwidth allocation to communicate with the management component. The management component may be programmed to look for alarm conditions or communication attempts from the ICs when predetermined parameter thresholds are reached.

Additionally, a signaling control mechanism between the management component and the ICs is disclosed. The signaling control mechanism operates to ensure that each of the ICs receives the appropriate message(s) and that the transmission plan may be implemented according to the predetermined schedule.

The signaling control mechanism between management component and implementation components may communicate by exchanging the following UDP/IP messages.

- Transmission Control Order
- Abort Order
- Acknowledgment of a Transmission Control or Abort Order
- Audit Request
- Audit Response

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A transmission control order ("TCO") specifies new transmission parameters for a transmitter or receiver. The TCO may also specify the implementation time. The implementation time may be the time at which elements should begin using the transmission parameters specified in the order. TCOs are generated by the system to implement a new transmission plan. The system sends TCOs to the ICs of transmitters and receivers that must change parameters to implement the new transmission plan. TCOs may be stored on a hard drive or other non-volatile storage so that they are preserved through IC restarts and at IC power failures.

15

It is possible that an IC may be down or may not be able to communicate with the managed equipment at the execution time of a TCO. When this happens, the IC may implement the current transmission plan or may implement a default state when the IC reestablishes communication with the managed equipment.

20

The IC may send an acknowledgment of a TCO when a TCO is received from the system. If any of the requested parameter changes cannot be implemented because the managed equipment or the configuration files do not support it, the IC notifies the management component of this in the acknowledgment.

25

The IC may also check that the parameter values are valid for the managed network equipment. Parameter ranges are specified in the Equipment Controller configuration files in the IC, discussed further below.

A confirmation message may not be necessary for reporting the successful implementation of a transmission control order. Because the majority of satellite networks

implement single links to each remote site, if an IC is not able to implement a TCO, the IP connection to the system may be lost. The system management component may detect the problem from the lack of audit responses. If the system does not receive an audit response from an IC, the system may update the site status and alerts the management component
5 alarm.

An abort order may instruct the IC to cancel any pending TCO for the specified transmitter or receiver. The system may send abort orders when a pending implementation is canceled by the Administrator. The IC may send an acknowledgment when it receives an abort order. The IC may send an acknowledgment when it receives a TCO or abort order
10 from the management component.

An audit request may be periodically sent to an IC by the management component. The management component may send an audit request to check the status of a transmitter or receiver. One audit request may be sent for each transmitter and receiver being managed by an IC.

15 An audit response may be sent by an IC when an audit request is received from the management component. The audit response may contain the current parameter values for the transmitter or receiver specified in the audit request.

An audit response may be similar in structure to a TCO. It may include the hardware identification for a transmitter or receiver and a list of model parameters and their current
20 values as reported by the physical hardware.

The receive frequency model parameter may be a special case: the frequency reported by the demodulator may not match the commanded receive frequency. Sources of frequency error throughout a wireless carrier transmission process may result in an offset between the expected and actual receive frequencies. Many demodulators are designed to accommodate
25 this frequency offset by searching for the transmitted carrier in a neighborhood around the

commanded receive frequency. However, the system may also account for this receive frequency offset when determining whether the physical hardware is using the same parameters as in the most recently implemented TCO.

The management component may periodically request the current parameters from all transmitters and receivers. This network auditing function may perform the following functions:

- Maintains the status of communications between the management component and the transmitters and receivers in the network.
- Detects parameter changes of the managed equipment.

When a difference between the specified transmission parameters for a transmitter or receiver and the managed equipment is detected, the management component may notify a Bandwidth Administrator. The management component operator interface may use an audible as well as visual alert to improve the chance that a Bandwidth Administrator will notice the difference and act to resolve it.

Fig. 21 shows equipment controller IC (150). IC (150) may have a configuration database (152) which stores a configuration mapping for end-user receiver and transmitter equipment which is interfaced by, for example, serial devices (164, 166, 172, 174) and parallel devices (188, 190). The receiver/transmitter equipment may be from multiple vendors and thus the configuration database (152) maps commands from the management component (156) to a particular device. This feature of the IC may allow the use of a generic network control language in commands sent to IC (150) (discussed further below).

The *system* is designed to manage all transmission equipment, regardless of manufacturer. To achieve this, the management component deals with model satellite transmitters and receivers as illustrated in Figure 6.

The transmitter and receiver models have the parameters necessary to implement a wireless link. Only parameters that relate to the establishment of a wireless link need be included in the transmitter and receiver models.

The management component may not require information about the physical equipment elements used to implement the communications links in the managed network. Therefore, the MC need not map the model parameters directly to commands for the physical hardware of the transmitters and receivers at a site. The IC may have information about the physical hardware at its site and may map the model parameters to the appropriate commands and responses.

The IC may read information about the physical hardware from the configuration files. These files may specify the information required by the IC to monitor and control the managed equipment at a site. The IC configuration files may contain the information necessary to convert parameter changes for the model transmitters and receivers into commands to the physical hardware.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a pictorial schematic of a star topology satellite network showing a shared outbound simplex channel and a private inbound simplex channel.

Fig. 2 is a pictorial schematic of a mesh topology for a satellite network showing shared outbound simplex channels.

Fig. 3 is a functional schematic of a transmission equipment model depicting modulators, up converters, and the loss and gain elements in the circuit, the site antenna, and the corresponding receiving circuits showing gain and loss elements, the down converter, and the demodulator.

Fig. 4 depicts software components for the semi-autonomous network management system of the present invention.

Fig. 5 is a functional schematic detailing the software components. At the control site there is a management (control) component, a display controller and an event logger component. At the remote site, there is the IC, the equipment controller component and a display controller and event logger component. The management transmission and receiver equipment is further shown as being controlled from the IC equipment control.

Fig. 6 is a functional schematic showing the elements of a transmission model that are controlled by the semi-autonomous ICs of the present invention.

Fig. 7 shows a further functional schematic of the IC systems.

Fig. 8 is a functional schematic showing the software process architecture of the semi-autonomous network management component.

Fig. 9 is a functional schematic of the information flow in the semi-autonomous components of the present invention.

Fig. 10 is a graphical depiction of the transmission plan allocation of available spectrum.

Fig. 11 is a graphical depiction of the transmission plans of a transmission plan schedule.

Fig. 12 is a graphical depiction of a transmission plan schedule implemented throughout a particular day.

Fig. 13 is a flowchart illustrating a method of transmission plan deployment and execution.

Fig. 14 is a flowchart illustrating a method of executing a bandwidth allocation request.

Fig. 15 is a graphical depiction of a UDP datagram format employed in the management components.

Fig. 16 is a functional schematic of the request/command flow direction of the present invention.

Fig. 17 is a flowchart illustrating a method of grading, employing, and implementing transmission plans within the network.

5 Fig. 18 is a graphical depiction of how the methodology of the present invention views transmission media as resources.

Fig. 19 is a graphical representation of the methodology of the present invention allocating transmission media resources.

Fig. 20 is a graphical depiction of a timing transmission plan implementation.

10 Fig. 21 is a graphical depiction of the command processing flow in the equipment controller.

Fig. 22 is a graphical depiction of the process flow for network audit processing.

Fig. 23 is a graphical depiction of the auto command flow with respect to timing.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

15 The system is composed of two software components, the Management Component ("MC") and the Implementation Component ("IC") that work together to monitor and control the transmission elements in a wireless network.

The MC includes an operator interface for configuring, monitoring, and controlling the capacity allocation activity in a wireless network. It may be a Win32 application that runs
20 on a Windows NT workstation which may be located at a network operations center (NOC). Configuration, monitoring, and control of the capacity allocation may be accomplished with the management component. The MC communicates with the other software component, the IC, using the Internet Protocol (IP) family of network protocols as illustrated in Figures 4 and 5.

The IC is the application that may communicate with the physical hardware elements implementing the communications links in a wireless network. The IC may be a Win32 application that runs on a computer located at each site in the network. The IC may read a set of configuration files that describe the network equipment to be monitored and controlled.

- 5 These configuration files may be text files and may be created and modified with a text editor program. In general, the configuration files are re-usable, that is the same configuration file may be used at multiple sites if the same network equipment is used at both sites.

As discussed above, the MCs and ICs communicate by exchanging IP messages.

- 10 Figure 5 is a representation of the connectivity between the management component and the IC in a wireless network. The IP connections may be implemented on the satellite network, through the Internet, or through a private network. A second physical communication path between the MC and the ICs may be used to establish IP communications. Typically, ICs do not communicate with other ICs; however, communication links may be established between components to further communication with the MC.

- 15 The management system is designed around several elements. These are the

- Transmission resource
- Site
- Transmitter
- Receiver
- 20 • Transmission element
- Transmission plan
- Implementation
- Schedule
- 25 • Execution time

A *transmission resource* may be a portion of a wireless capacity (power and bandwidth) that may be used by the transmitters in a network. A *site* may be a collection of transmitters and receivers controlled by a single IC. Normally one IC controls all of the transmitters and receivers at a network site. However, the transmitters and receivers at a network site may be

controlled by more than one IC. For example, this may occur at a hub site in a satellite network with a star configuration.

A *transmitter* is an equipment element that modulates an information signal so that it may access a wireless media. A *receiver* is an equipment element that demodulates a signal
5 received from a wireless media to recover the information from the broadcast signal. A *transmission element* may be a transmitter or receiver in the network configuration. Although transmitters and receivers may be different and perform different functions, the management component may perform some operations in which transmitters and receivers are both treated the same way. For example, the MC may audit the status of all transmitters and receivers in
10 the network. The management component may not distinguish between transmitters and receivers when performing this auditing operation.

A wireless link may be created when an information signal is modulated by a transmitter and then demodulated by one or more receivers. A wireless communication network is a collection of communications links that enable information transfer among the
15 sites in the network. Each link requires some of the transmission resources available to the wireless network. The allocation of the available transmission resources among the transmitters in a network is a *transmission plan*. These transmission plans may define the information capacity and connectivity requirements between the transmitters and receivers in the network.

20 Only transmitters may need to be specified in a transmission plan. Transmitters generate the signals that use transmission resources. The number of receivers demodulating a wireless signal does not affect the amount of transmission resources (bandwidth and power) used to implement the link.

Implementation may be the process of configuring the transmitters and receivers in a
25 wireless network to allocate the transmission resources as specified in a transmission plan.

The management component may implement a transmission plan by sending orders to the ICs controlling the transmitters in the transmission plan and the receivers listening to those transmitters. These orders may specify the transmission parameters for the transmitters and receivers and when they should be implemented. The IC may send the equipment-specific commands that implement the transmission parameters at the specified time. The *implementation schedule* may be a list of all transmission plan implementations that may automatically be executed in the future. The schedule may be maintained by the MC application. An operator may add implementations to the schedule, remove implementations from the schedule, and move existing implementations to different times. An *execution time* consists of a transmission plan and the time at which the transmission will be implemented. The time may be a recurring time, for example 1200 UTC every day or 0600 UTC every Monday. The implementation schedule may be built from execution times.

The information architecture of the system applies primarily to the structure of the database maintained by the Management Component and may define the structure of the messages exchanged between the management component and ICs.

The information maintained by the management component (network configurations, transmission resource configurations, transmission plans, etc.) may be stored in a relational database.

The management component may require information about the wireless networks that it manages. A network may be viewed as being composed of sites, transmitters, and receivers. Information about these objects, *e.g.*, sites, transmitters and receivers, and the relationships among them may constitute a *network configuration*. A *network* may be a collection of sites that are linked by transmission resources. The following information may be specified for each network managed by the system:

- ☐ Name
- ☐ Transmission resources available for use by the network

5 The system may maintain the following information for each network:

- ☐ Network ID
- ☐ Status
- ☐ Sites in the network

10 A *site* may be the physical location of an antenna in a wireless network. In addition to an antenna, a site may have at least one transmitter or receiver. The system may require that the following information be provided for each site:

- ☐ Name
- ☐ NMS IP address
- 15 ☐ Location (street address, geographic coordinates, etc.)
- ☐ Contact information (telephone numbers, operators' names, radio frequencies, etc.)
- ☐ Antenna parameters (size, gain, etc.)

The system may maintain the following information for each site:

- 20 ☐ Site ID
- ☐ Status
- ☐ Network to which the site belongs
 - ☐ Transmitters at the site
 - ☐ Receivers at the site
- 25 ☐ Time of last management component transmission to site
- ☐ Time of last IC response from site

In the system, a *transmitter* may comprise the equipment necessary to convert a digital data stream into a carrier for transmission over a wireless resource. The system may require that

30 each transmitter be uniquely named. The system may maintain the following information for each transmitter:

- ☐ Transmitter ID
- ☐ Status (UP, DOWN, FIXED, UNKNOWN)
- ☐ Site where the transmitter is located
- 35 ☐ Receivers that should be receiving the transmitter's carrier(s)

The system may track the status of the transmitters in a wireless network. Possible status values for the tracked components may be:

- | | | |
|----|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 5 | UP | the transmitter is currently generating a carrier and is under the control of the management component |
| | DOWN | the transmitter is not generating a carrier but is under the control of the management component |
| 10 | FIXED | the transmitter is generating a carrier and the management component knows the characteristics of the carrier but the transmitter is not under management component control |
| 15 | UNKNOWN | the management component does not know if the transmitter is generating a carrier |

In the system, a *receiver* may comprise the equipment necessary to receive a carrier transmitted over a wireless resource and recover the digital data stream. The following information may be specified for each receiver:

- | | |
|----|---------------------------------------------------------------------------------|
| 20 | <input type="checkbox"/> Name |
| | <input type="checkbox"/> Transmitter of the carrier the receiver should receive |

The system may maintain the following information for each receiver:

- | | |
|----|-------------------------------------------------------------|
| 25 | <input type="checkbox"/> Receiver ID |
| | <input type="checkbox"/> Status |
| | <input type="checkbox"/> Site where the receiver is located |

A *pool* may be a collection of transmission resources available for use by the managed networks. Each transmission resource is a portion of transmission capacity (power and bandwidth). The following information may be required for each pool:

- | | |
|----|-------------------------------------------------------------|
| 30 | <input type="checkbox"/> Name |
| | <input type="checkbox"/> Transmission resources in the pool |

The system may maintain the following information about each pool:

- ☐ Pool ID
- ☐ Networks using the pool

5 A *transmission* resource may be a portion of transmission capacity (power and bandwidth). The system may require the following information about each transmission resource:

- ☐ Description (transponder, provider, etc.)
- ☐ Start frequency
- 10 ☐ End frequency
- ☐ Translation offset
- ☐ Power allocation
- ☐ Cost metrics

15 The system may maintain the following information about each transmission resource:

- ☐ Transmission resource ID
- ☐ Pool to which the Transmission resource belongs

 A *transmission plan* is an allocation of transmission resources to one or more carriers
20 in a wireless network. The system may specify the following information about a transmission plan:

- ☐ Execution time
- ☐ Duration
- 25 ☐ Comments

 The system may maintain the following information about a transmission plan:

- ☐ TP ID
- ☐ State (UNSCHEDULED, SCHEDULED, PENDING, READY, STARTING, ACTIVE, COMPLETED, or CANCELLED)
- 30 ☐ BARs satisfied by the TP

 The system may manage sites with multiple transmitters and receivers. Therefore the system maintains a naming scheme for identifying a specific transmitter or receiver at a site.

Figure 9 may represents the flow of hardware identification information from the IC configuration files to the management component. The identification information may originate in the configuration files generated for a site in a network. The configuration files for a site may be read by the IC.

5 Figure 9 shows the information flow in the system. Each transmitter and receiver at a site may be designated by an equipment class. Each member of a class is assigned an instance number. Together, the equipment class and instance identify a unique transmitter or receiver at a site. A Bandwidth Administrator (902) may supply the hardware identification when configuring the transmitters and receivers of a site for bandwidth management. The
10 flow of information shown in figure 9 simplifies network configuration maintenance and reduces the risk of problems due to inconsistent configuration information in the network. The circles with a slash (914, 916) illustrate that neither the Bandwidth Administrator (902) nor the management component (906) require access to the configuration files (910).

 The system software components may exchange information by sending and receiving
15 messages using network or external connections. The management process may communicate with all of the IC processes. Each IC communicates only with the management component.

 The User Datagram Protocol (UDP) of the Internet Protocol (IP) suite may be used to transport the inter-process messages. The system may use the combination of IP address and
20 UDP port to identify the ICs in the network. Site identification information may not be required in the message if the IP address and port are already available in the IP and UDP headers.

 The management and ICs may communicate using several types of messages.

 Although each type of message contains different information and fulfills a different purpose,
25 the message types share some common characteristics as shown in Figure 15.

- ☐ A message is sent as a single UDP datagram
- ☐ Only ASCII characters are allowed in a message
- ☐ A message is a series of information fields
- ☐ Fields are terminated with an ASCII linefeed (LF)
- 5 ☐ A message is terminated with an empty field (single LF)
- ☐ The first three fields are the same for any message (message type, sequence number, and hardware identification)

Although system messages contain only ASCII characters, the messages may be compressed
10 before delivery via UDP. Messages may then be uncompressed after receipt. Fields #4 through #N (1514, 1518) in figure 15 are *information fields* (1524). The fields prior to the information fields in a BMF message are *header fields* (1528).

Header fields may be present in system messages (1528). Typically, the order and format of the header fields are the same, regardless of message type. The format of a header
15 field is simple: a string terminated by an ASCII linefeed (LF) character (1504, 1508 and 1510). The string can contain any printable ASCII character except LF. The management and ICs may communicate using the following message types:

- ☐ Transmission Control Order (TCO)
- ☐ Abort Order (ABRT)
- 20 ☐ Acknowledgment (ACK)
- ☐ Audit Request (AREQ)
- ☐ Audit Response (ARSP)

The mnemonic in parentheses after each message type is the identifier used in the first
25 field (1502) of a system message (1526). After the message type field, the next field in a system message is a sequence number (1506). The management component maintains a sequence number for each piece of managed equipment (e.g. receiver or transmitter) in a network. The IC may use the sequence number from a request message in the response message.

30 Sequence numbers may be used to match responses (ACK or ARSP) with requests (TCO, ABRT, or AREQ). The use of sequence numbers (1506) prevents confusion when

multiple responses are received when multiple requests were sent due to message delivery delay or temporarily unavailable components.

Figure 18 illustrates a transmission plan for allocating transmission media resources among transmitters in a network. Figure 18 shows that a transmission media can be divided up into discrete segments (10). A network management plan can view discrete segments (10) of bandwidth as discrete transmission media sources (12). A transmission plan (16) may be used to map a network transmitter (18) through a link (14) to a predefined transmission media resource (12). For example, transmission network transmitter (20), in particular transmitter (18), may be mapped through transmission plan (16) to two discrete segments (10) through link (14). The network media resource may be a star topology as shown in Fig. 1 or a mesh topology as shown in Fig. 2.

Network transmission media resources may also be on separate networks. For example, a first network transmission resource may be capacity from the INMARSAT satellite network or through private networks on a C, KU, KA or L-Band. The network transmission resources may be further augmented by low earth orbiting satellites, medium earth orbiting satellites or geosynchronous satellites. Low earth orbiting satellites may be represented by the Iridium system employed by Iridium, Inc., whose discrete bandwidth allocation methodology is herein incorporated by reference. Geosynchronous satellites may also provide additional transmission resources as represented by the Inmarsat or Intelsat satellite services whose bandwidth allocation methodologies are herein incorporated by reference.

The management component or the ICs do not need to be in direct control of the bandwidth allocation to utilize transmission media sources. For example, bandwidth allocation on the Iridium satellite system may operated independently of the management component and the ICs. However, the bandwidth allocation methodologies of, for example, the Iridium network, may be employed to treat the resultant communication path as a

transmission media resource under control of the management component. Indeed, multiple carriers from a third-party system may be allocated in discrete predefined units, such as discrete segments (10), shown in Fig. 18, for utilization by the present invention as a media resource.

5 Fig. 19 is a graphical depiction of network elements, ICs, a management component and a transmission plan. A central controller of the present invention may be represented by Management Component ("MC") (30). MC (30) is in communication with a plurality of ICs ("ICs") (32, 34, 38, 40) through links (31). Each IC may represent a particular site that is under network management control by the MC. Each IC may have network equipment (42)
10 under its control. For example, IC (40) has transmitter (44) under its control and BIC (38) has receivers (46, 48, 50, 51) and transmitters (56, 57) under its control. IC (36), however, has receiver (54) and transmitter (52) under its control. The present invention implements a transmission plan (43) through a mapping of network equipment (42) to transmission media resources (46). For example, transmitter (44) has been allocated transmission media resource
15 (45) for reception by receiver (48) as indicated through up link and down link mappings in transmission plan (43). This may represent a combined transmission media resource whose overall capacity is the entire discrete amount allocated at transmission media resource (45). For example, a dynamic bandwidth requirement for a connection at a predefined class of service may be split into two discrete carriers. The discrete carriers may be represented by the
20 two discrete media resources allocated at transmission media resource (45) to provide an overall throughput necessary to accommodate the predetermined capacity to support the class of service. The excess capacity may be used to provide the time recovered to reassemble the packets at receiver (48). This methodology is useful in the instance where, for example, a class of service from a particular end-user exceeds the network capacity to satisfy the demand
25 on a single channel or contiguous media resource. For example, the class of service requires

a connection that exceeds the bit rate capacity of the modulator at a particular transmitter, but two modulators would supply ample bandwidth for the class of service. In that instance, the IC or the management component could divide a packet data stream from the end-user device onto the two different modulators. In that instance, multiple transmission media resources
5 may be allocated to satisfy the overall class of service demand.

A further representative example of a transmission plan employed herein is a broadcast from IC (38) through transmitter (56) which has been allocated transmission media resource (57). Transmission media resource (57) may be used for reception by both IC (34) and receiver (58) and IC (32) and receiver (60). This is an example of a point to multi-point
10 broadcast. The point is represented by uplink transmitter (56) and the multi-points are represented by receivers (58) and (60). One representative application of such a plan is, for example, a broadcast message from transmitter (56) to two simultaneous sites represented by ICs (32) and (34).

Another representative example of a transmission plan employed herein is transmitter
15 (57), under control of IC (38), having an allocation of transmission media resource (61) for reception by receiver (54). IC (36) has transmitter (52) and transmission media resource (53) allocated for reception by receiver (50) at IC (38). This transmission plan may represent an asymmetric transmission, *i.e.*, the outbound channel from IC (38), represented at transmitter (57), has more media resources allocated which may indicate a higher bandwidth or higher
20 data rate for reception by IC (36) through receiver (54) than the outbound channel from IC (36) through transmitter (52) through transmission media resource (53) for reception by receiver (50) to IC (38). Other representative permutations of the transmission plans employed herein are shown in Fig. 19 through the mapping transmission plan (43).

Fig. 20 demonstrates the timing of how a representative transmission plan may be
25 implemented by the management component. The transmission plan implementation begins

with management component (100) having a predetermined command (102) to send to the network at a predetermined command time (110). Command(s) (102) is sent to IC (104) that must change transmission resource allocation at the implementation time. This command is stored in IC (104) and the time to implement the command is decoded by IC (104). IC (104) then sends a command acknowledgment (118) back to a management component (100). At this juncture, command (102) is loaded and awaits deployment at MC (100) at the predetermined command time (110). Command (102) is resent (122) if acknowledgment of receipt of command (118) is not received before a predetermined time.

It is understood that MC (100) may have a list of every IC (104) in the network that must change. This list may include the TCP/IP address for each IC (104) so MC (110) may send a UDP/IP message with a command (102) encoded therein. An acknowledgment deadline (134) is included that may be seconds before the implementation time for the new transmission plan. The acknowledgment deadline (134) may be the last time at which MC (106) can abort an implementation if each IC (104) does not acknowledge the commands.

It is understood that IC (104) may use a coordinated implementation to assure that no IC (104) is stranded when the transmission plan is implemented. During the abort sequence, which occurs if IC (104) has not acknowledged command (102) at step (118), MC (106) sends an abort message (126) to IC (108) that were sent command (102). IC (108) may send an abort acknowledgment (128). Abort command (126) is resent at step (130) if it is not acknowledged. The implementation time (136) defines a time at which the transmission plan is executed by IC (104). It is understood that at that point, all necessary ICs (104) have acknowledged command (118) and are counting down in a synchronized fashion to the predetermined implementation time (136). It is understood that the command acknowledged may include an indication of the time at which an IC (104) received command (102) to verify that the implementation time (136) is synchronized among each IC (104). Once all

commands have been acknowledged and the network is ready to implement the plan, at implementation time (136), the ICs (104) implement the command(s) received from MC (100) at implementation time (136).

At this point, a new transmission plan, as depicted in Fig. 19, may be implemented by the network. The communication path between MC (30) and ICs (32, 34, 36, 38, 40) is independent of the transmission media resources. As depicted in Fig. 19, a transmission path (31) is generally over a TCP/IP network (*e.g.*, the Internet), as widely known in use today. However, it is within the scope of the present invention to define a guard or maintenance channel which may be a point-to-multi-point transmission scheme from MC (30) to and from ICs (32, 34, 36, 38, 40) wherein an IC co-located with MC (30) assures that a network connection is present between ICs (32, 34, 36, 38, 40) and a MC allocated transmitter, such as transmitter (44). In such a case, each IC (32, 34, 36, 38, 40) ready to implement the new transmission plan may have a receiver dedicated to monitor transmitter (44) to receive abort command (126) if each IC (32, 34, 36, 38, 40) does not acknowledge. This assures a fail safe or guard channel back-up plan to abort implementation of a new transmission plan if one or more IC (32, 34, 36, 38, 40) loses communication with the management component.

Commands may enter the IC (150) from a plurality of sources, one of which may be directly from the MC. Node (158) may be a UNIX daemon or a Windows NT™ service which monitors a TCP/IP address. Thus, commands from MC (156) may enter IC (150) through a port (204). Upon entering IC (150), network commands may be mapped at step (158) in conjunction with configuration database information to output specific commands (178) to the network equipment. These commands may be put into a command queues (168, 180, 184) which is then directed through a scheduler process 162, 170 and 186. For example, scheduled command implementation processes (162, 170, 186) may output commands to the appropriate receiver, transmitter or network device through a serial port (164, 166, 172, 174)

or a parallel port (188, 190). Command queues (168, 180, 184) may be a polled or interrupt driven queue. That is, the schedule command implementation process (164) may periodically poll queues (168, 180, 184) to determine whether a command is present, and if so, pass the command on to the appropriate network device interfaced (e.g., serial device driver (164, 166)) or the command key may be a period.

The command queue may alternatively be interrupt driven. That is, when a command enters queue (168, 180, 184), for example, command queue (168) may send an interrupt to the command implementation process for the command implementation process to service the command and then pass it to the appropriate network device at the appropriate serial port. It is understood that this process may be used for implementation processes (170, 186) as well.

Command implementation processes (168, 170, 186) may be synchronized to network time (202) to execute commands at the appropriate time. That is, implementation of transmission plans may be synchronized with network time (202) to assure that all network devices reconfigure themselves simultaneously or near simultaneously. Implementation processes (168, 170, 186) may also have data from configuration database (152) to configure implementation process (168, 170, 186) for the particular end-user network device. This provides flexibility in implementation process (168, 170, 186). That is, the implementation may be written as a modular software program which may be modified by configuration database data (160) as implementation process (168, 170, 186) executes. Further to this concept is that MC (156) may address configuration database (152) via link (204) to change configuration database (152) to redefine the end-user equipment. This allows the MC (156) to manage the end-user equipment remotely from the user location at the IC site. IC (150) may communicate through module (158) via link (182) to send acknowledgments (200) back to the MC (156). Command acknowledgments (118) shown in Fig. 20 and order

acknowledgments may also be used. Figs. 21-28 illustrate a step that may be used to confirm receipt of commands or to confirm receipt of an abort command.

It is understood that there are at least two ways in which to map MC commands or at least two ways in which to map MC commands to the end-user device or to a particular port on a IC. First, a TCP/IP address is provided for the IC in command (204) and then, within the UDP command, is a sub-address that may be decoded at (158) addressed to a particular end-user device.

Fig. 22 shows a graphical block diagram of an audit control process by which the present invention may collect data from network equipment. Equipment controller (150) may have a configuration database (152) which controls the configurations of the IC in relation to the end-user network equipment. An audit request (252) may be received from the MC via port (254). Port (254) may be a user data packet via a TCP/IP network to a particular predetermined address at (256). At (256), an auto request command may be decoded to map an equipment name to hardware identification from those stored in configuration database (152). The process at (256) may also be used to map equipment attributes to data controls (290). These parameters may be passed to the reformat command process at (280) which is used to provide a formatted audit response (282) to the MC.

In one embodiment of the present invention, the MC may establish an asynchronous data collection process (262, 264, 266) for the network equipment at a respective data port (268, 270, 272, 274, 276, 278) for the network equipment. Asynchronous data collection process (262, 264 266) may be interrupt or poll driven.

In the interrupt driven embodiment of asynchronous data collection process (262, 264, 266), the end-user device may send out an unsolicited command via the respective device (e.g., device 268), to asynchronous data collection process (262, 264, 266). The interrupt then invokes the program to service the data condition (or possibly an alarm) from the

network equipment. Asynchronous data collection process (262, 264, 266) then moves the data to the data control store block (258) where the alarm or data condition may be stored in the IC. It is understood that the data control store block (258) may be a hard drive or other long term storage means available at the BIC. In a preferred embodiment, the data control store is a non-volatile data storage media and the asynchronous data collection process is a modular program because it is modified from data from configuration database (260) for the particular network device. This provides a flexible programming methodology for the asynchronous data collection process employed in the present invention.

In the polled embodiment of asynchronous data collection process (262, 264, 266), asynchronous data collection process (262), for example, may periodically poll the end-user network device attached to, for example, port (268), to receive data or alarm conditions from the end-user device. The polling rate may be a parameter from the configuration database received via link (260).

In sum, an audit request may be received via port (254) and decoded at (256) to output data from the data control store program (292). Data output from the data control store may be formatted at (280) from parameters past (290) from the audit request. This can provide an auto response (294) back to the BMC (282) in the appropriate and predetermined format.

Fig. 23 shows a logic flow representation of a network audit from a MC (302). In Fig. 23, the MC (302) may establish an auto time for a network element, a transmitter or receiver (300). At the appropriate time, MC (302) may send out an audit request (306). It is understood that audit request (306) is directed to the network element and the particular IC controlling that element (308). The IC may then query the network element and send an audit reply (312) to the MC (310). Audit reply (312) is shown in time synchronization (316) after audit request (306).

Initialization or configuration files may be used to implement the invention. Exemplary initialization files are shown in Appendices A-H. For example, a "command.ini" file (shown in Appendix A) may be used to provide user interface command definitions for all network management system equipment supported. The "command.ini" file specifies the
5 menus associated with each control used on a user display.

A "monitor.ini" file (shown in Appendix B) may be used to specify automatic monitoring functions performed by an equipment controller. The "monitor.ini" file may act as the network management system data connection interface definition file.

An "equipctl.ini" file is shown in Appendix C. The "equipctl.ini" file may be used
10 as the network management system controller initialization file. That is, the "equipctl.ini" file specifies some global parameters for the equipment controller application. It may also specify the location of other configuration files if such files are not stored in a default or pre-determined location.

Appendix D shows an exemplary "event.ini" file. The "event.ini" file may provide
15 descriptions of network management system events. For example, the "event.ini" file may specify textual responses (to user commands) displayed on a user interface and the asynchronous messages sent to either an event logger or other device.

A "port.ini" file (shown in Appendix E) may be used as the network management system external connection definition file. The "port.ini" file may specify particular serial
20 and parallel ports used by the equipment controller application.

Appendix F shows an example of a "serial.ini" file. The "serial.ini" file may be used as the network management system serial command description file. This file may specify the command and response strings used to communicate with the manage equipment over a serial interface.

An example of a network management system user interface definition file ("panel.ini" file) is shown in Appendix G. The "panel.ini" file may be an the overall specification for the display controller presentation. This file ties together the display controls with specific input/output ports and describes the total graphic user interface for an
5 equipment controller site.

Appendix H shows an exemplary "template.ini" file. The "template.ini" file may be used as the network management system display template description file. This file specifies the graphic qualities of the controls used in the display controller presentation. Graphic qualities may include the position of the graphic control on a display, the type of display
10 object, the name of any required bitmap graphic file, and a reference to any menu associated with the control.

The hardware identification field (1510) may contain information that identifies a specific transmitter or receiver at a site. The hardware identification field may have the format:

15 HWID=<Class>:<Name>

where

<Class> is the type of hardware and

<Name> is the name assigned to a specific piece of hardware in the IC configuration.

The type of hardware may be one of the following classes:

- 20
- ☐ Transmitter (TX)
 - ☐ Receiver (RX)
 - ☐ Upconverter (UC)
 - ☐ Downconverter (DC)

25 The <Class> portion of the hardware identification field may be one of the mnemonics shown in parentheses. Information fields (1524) and header fields (1528) may share some similarities. Each type of field is terminated with an ASCII linefeed (LF) character (1512,

1522). The primary difference between header fields (1528) and information fields (1524) is that the same header fields are found in all system messages while different messages can have different information fields.

Because of the size of information fields (1524), the format of an information field is more complex than the format of a header field. Information fields may match the format:

<mnemonic>=<value>

where

<mnemonic> is a mnemonic representing the field type and

<value> is a string representation of the field value.

Both the mnemonic and the value of an information field may consist of printable ASCII characters. However, the ASCII character '=' is used to separate the mnemonic and value portions of an information field. Therefore, '=' cannot be present in either the mnemonic or value strings.

A *transmission control order* (TCO) is sent from management component to an IC to request parameter changes for a transmitter or receiver controlled by the IC.

A TCO may have the following information fields:

- ☐ Execution time
- ☐ Model parameters

The execution time field specifies the time at which the TCO must be implemented. The TCO for each side of a communication link (transmitter and receiver) may have the same execution time to minimize the time the carrier is down during the change. Execution times may be given in UTC. The execution time field may have the format:

ET=<YYYY><MM><DD><hh><mm>

where

<YYYY> is the four-digit year number (0000 to 9999),

<MM> is the two-digit month number (January is "01", etc.),

<DD> is the two-digit day of the month (01 to 31),

<hh> is the two-digit hour of the day (00 to 23), and

5 <mm> is the two-digit minute of the hour (00 to 59).

All of the fields in a TCO after the execution time are model parameters. These fields are the parameter values for the transmitter or receiver specified by the hardware identification field of a TCO. Model parameters are specified as a parameter/value pair. The
10 format of a model parameter in a BMF message is:

<mnemonic>=<value>

where

<mnemonic> is the mnemonic for a model parameter and

<value> is a string representation of the parameter value.

15

An *abort order* (ABRT) may be sent to an IC to cancel any pending TCO for the specified hardware. An ABRT does not require any information fields.

An *acknowledgment* (ACK) informs the management component that the IC received the TCO or ABRT. An ACK is the response message for a TCO or ABRT. When an IC
20 receives a TCO or ABRT, it must send an acknowledgment to the management component. If the IC detects any problems with the TCO (configured hardware does not support a model parameter, hardware ID invalid, etc.) then the ACK will describe the problems. An ACK for an ABRT does not require this problem description. An ACK may have the following information fields:

25 □ Execution time (same as in TCO)

- Model parameters (only if an error condition exists)

An ACK may have the same information fields as the TCO that is being acknowledged. However, model parameter fields are only present if the IC cannot fulfill that model parameter. For example, if the TCO contained an invalid receiver bit rate but a valid receiver frequency then the ACK would include an information field for the RXR model parameter but not for the RXF model parameter.

An *audit request* (AREQ) is sent periodically by the MC for each transmitter and receiver in a satellite network. Each AREQ is sent to the BMF IC responsible for managing the specified transmitter or receiver. An AREQ does not require any information fields.

An *audit response* (ARSP) is sent by an IC in response to an AREQ from the MC. An ARSP is the response message for an AREQ. An ARSP has the following information fields:

- Execution time (time ARSP generated)
- Model parameters (actual settings)

The format of an ARSP may be almost identical to the format of a TCO: the message contains an information field for all of the model parameters pertaining to the specified piece of hardware. However, the values of the model parameters may be the actual settings of the hardware, not the desired settings.

One purpose of the ARSP is to determine the state of the hardware in the network. A secondary purpose is to check for manually instituted changes to the configuration of the network hardware. For example, an operator at a remote site might manually change the receiver frequency using the front panel of the equipment. The management component periodically requests the current state of all managed equipment to check for parameter modifications not initiated by the management. The execution time for an audit response is the time at which the ARSP is generated.

An ARSP may contain the model parameters for the type of equipment specified by the hardware identification. When the value for a model parameter is not available, the value portion of the field may be "UNKNOWN". For example, if the scrambling state of a transmitter cannot be determined by an IC, the field "SCR=UNKNOWN" may appear in the audit response.

The IC (IC) may read its configuration files at startup and construct memory resident database tables and data 'objects' to facilitate rapid access to the configuration information stored in those files. Among the data read from the configuration files are the records that describe the equipment that the Management Console (MC) application will attempt to control by its commands to the Equipment Controller. The MC may communicate with the Equipment Controller in message with a format similar to:

Equip=EquipmentClass:EquipmentUnitName

Attribute1=Value1

Attribute2=Value2

where 'EquipmentClass' and 'EquipmentName' are character string values that occur in the IC configuration files as identifying a piece of modeled equipment. The values of 'Attribute' and 'Value' are also represented as character strings and hence the entire dialog between the MC and IC is through text based messages.

The IC configuration files identify one or more pieces of modeled equipment and a set of attributes that the modeled equipment can support. For example, the following section of an 'equipctl.ini' file describes an equipment element known as 'TRANSMITTER:Outbound'. The modeled attributes are identified by the 'EquipModemAttrs' entry and list the values TXF

TXR MODT MODR ENCT ENCR DENC SCR PWR CXR as the legitimate attributes of the unit known as 'TRANSMITTER:Outbound'.

[Outbound]

- 5 EquipName=Outbound
EquipClass=TRANSMITTER
EquipModelAttrs=ALL TXF TXR MODT MODR ENCT ENCR DENC SCR PWR CXR
EquipAttrSetCmds="" EFDataTxfSetCmd EFDataTxrSetCmd EFDataModtSetCmd
EFDataModrSetCmd EFDataEnctSetCmd EFDataTxrSetCmd EFDataDencSetCmd
10 EFDataScrSetCmd EFDataPwrSetCmd EFDataCarrierSetCmd
EquipAttrSetCmdParms="TXF TXR ENCT PWR" "TXF" "ENCR TXR" "MODT" "MODR"
"ENCT" "ENCR TXR" "DENC" "SCR" "PWR" "CXR"
EquipAttrSetCmdPorts=Serial5
EquipAttrSetCmdAddrs="1"
15 EquipAttrMonConns="" EFDataTxfMon EFDataTxrMon EFDataModtMon
EFDataModrMon EFDataEnctMon EFDataEncrMon EFDataDencMon
EFDataScrMon EFDataPwrMon EFDataCarrierMon
EquipAttrMonConnPorts=Serial5
EquipAttrMonConnAddrs="1"
20 AssociatedEquipment=RECEIVER:Demod1

This configuration entry may also associate other configuration entries with the equipment attributes that permit the equipment controller to set (modify) and get (recover) the attribute values from an actual piece of serially attached equipment. The entries in the list of

- 25 'EquipAttrSetCmds' refer to entries in the 'serial.ini' file that describe the actual command to

be sent. The entries in the 'EquipAttrSetCmdPorts' and 'EquipAttrSetCmdAddrs' describe which serial port the attached equipment is connected to and the address of the attached equipment (in the case that multiple pieces of equipment are attached via the same serial port). Similarly, the 'EquipAttrMonConns' entry refer to configuration entries in the

5 'monitor.ini' file that describe the mechanism by which the attribute is recovered from the attached equipment and the 'EquipAttrMonConnPorts' and 'EquipAttrMonConnAddrs' describe the serial ports and addresses used for data recovery.

Hence the IC is in not actually aware of the semantics of the data values it is 'setting' or 'getting' and the mapping between the equipment and equipment attributes that the MC

10 believes it is controlling is completely defined by the equipment controller configuration files and not equipment controller software.

The MC and IC communicate via the text format generally described above. All communication is initiated by the MC. Three request packets are currently defined: 1) a request to modify the attributes of a particular piece of equipment at a particular time in the

15 future, 2) a request to cancel the request to modify the attributes of a particular piece of equipment, and 3) a request to return the current values of the attributes of a particular piece of equipment. Each request is normally responded to with a complementary message. In some cases, however, no response message purposely generated in order to communicate a negative response.

20 The request to modify the attributes of a particular piece of equipment is known as a Transmission Change Order (TCO). The format of a TCO is as follows:

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

Time=YYYYMMDDHHMM

Attribute1=Value1

Attribute2=Value2

- 5 When the IC receives a TCO it validates the request. The request validation includes confirming that the requested change time has not already past and that the IC configuration supports the requested modifications. The IC may refer to its memory resident database of configuration data to validate request. First, the IC may insure that the requested equipment is identified in the configuration. It then may insure, by tracing the attributes named in the
- 10 request through the configuration to the commands that must be issued to insure that sufficient configuration information is present to form the required commands. Finally it may check to see if the equipment is currently responding to commands.

- If an error is detected such that the request cannot be supported by the configuration, a response may be returned to the MC identifying the offending request data. For example, if a
- 15 request contained an equipment identification that did not exactly match an entry in the 'equipctl.ini' file or if an attribute name did not exactly match one of the legitimate attributes named in the 'equipctl.ini' file, a response would be sent indicating why the TCO was invalid and implicitly indicating that the request would not be implemented. Further, if a legitimate attribute is named, but the equipment controller finds that either no serial command is
- 20 referenced or that the referenced serial command is not configured, the IC may also send a similar response indicating why the request cannot be implemented. Validation of the parameter values may also be accomplished in a similar technique.

- If the request is otherwise correct, but the equipment is currently not responding to serial commands, no response is purposely generated, which may indicate that no problem
- 25 was detected in the request but that the since no acknowledgment was sent, the request will

not be implemented at the specified time. Otherwise, an acknowledgment is returned to the MC indicating that unless otherwise instructed, the IC will perform the requested configuration change at the requested time. The request to cancel the modification of the attributes of a particular piece of equipment is known as a Abort Message (ABRT). The
5 format of an ABRT is as follows:

ABRT

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

10

The IC may remove the outstanding command set to be issued to the specified equipment if any command is queued and may send an acknowledgment to the MC indicating it has done so. If, at the time of receipt, no command is outstanding, the IC may respond with a message indicating that no command was found. The request to recover the current values
15 of the attributes of a particular piece of equipment is known as an Audit Message (AUDIT).
The format of an AUDIT is as follows:

AUDIT

MessageSequenceNumber

20

Equip=EquipmentClass:EquipmentUnitName

AttributeName (optional)

AttributeName (optional)

The MC may request the current values of the equipment attributes by sending an
25 AUDIT message to the IC. The message may contain specific attribute names or, in the

absence of any attribute names, all attributes associated with the equipment are returned.

Should the equipment or attributes identified not be defined in the IC configuration, the IC will send a message similar to the negative acknowledgment to a TCO indicating what particular field of the request message was found in error. If the AUDIT request message is found to be supported by the current IC configuration, the IC may will use the configuration entries identified by the 'equipctl.ini' file to recover the current values and will form a response message similar to the TCO message and send it to the MC. The response message format is as follows:

10 AUDIT

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

Time=YYYYMMDDHHMM

Attribute1=Value1

15 Attribute2=Value2

The Implementation component (IC) reads its configuration files at startup and constructs memory resident database tables and data 'objects' to facilitate rapid access to the configuration information stored in those files.

20 Among the data read from the configuration files are the records that describe the equipment that the Management Console (MC) application will attempt to control by its commands to the Equipment Controller. The MC will communicate with the Equipment Controller in message with a format similar to:

Equip=EquipmentClass:EquipmentUnitName

Attribute1=Value1

Attribute2=Value2

- 5 where 'EquipmentClass' and 'EquipmentName' are character string values that occur in the IC configuration files as identifying a piece of modeled equipment. The values of 'Attribute' and 'Value' are also represented as character strings and hence the entire dialog between the MC and IC is through text based messages.

- 10 The IC configuration files identify one or more pieces of modeled equipment and a set of attributes that the modeled equipment can support. For example, the following section of an 'equipctl.ini' file describes an equipment element known as 'TRANSMITTER:Outbound'. The modeled attributes are identified by the 'EquipModemAttrs' entry and list the values TXF TXR MODT MODR ENCT ENCR DENC SCR PWR CXR as the legitimate attributes of the unit known as 'TRANSMITTER:Outbound'.

15

[Outbound]

EquipName=Outbound

EquipClass=TRANSMITTER

EquipModelAttrs=ALL TXF TXR MODT MODR ENCT ENCR DENC SCR PWR CXR

- 20 EquipAttrSetCmds="" EFDataTxfSetCmd EFDataTxrSetCmd EFDataModtSetCmd

EFDataModrSetCmd EFDataEnctSetCmd EFDataTxrSetCmd EFDataDencSetCmd

EFDataScrSetCmd EFDataPwrSetCmd EFDataCarrierSetCmd

EquipAttrSetCmdParms="TXF TXR ENCT PWR" "TXF" "ENCR TXR" "MODT" "MODR"
"ENCT" "ENCR TXR" "DENC" "SCR" "PWR" "CXR"

EquipAttrSetCmdPorts=Serial5

EquipAttrSetCmdAddrs="1"

EquipAttrMonConns="" EFDataTxfMon EFDataTxrMon EFDataModtMon

EFDataModrMon EFDataEnctMon EFDataEncrMon EFDataDencMon

5 EFDataScrMon EFDataPwrMon EFDataCarrierMon

EquipAttrMonConnPorts=Serial5

EquipAttrMonConnAddrs="1"

AssociatedEquipment=RECEIVER:Demod1

- 10 This configuration entry also associates other configuration entries with the equipment attributes that permit the equipment controller to set (modify) and get (recover) the attribute values from an actual piece of serially attached equipment. The entries in the list of 'EquipAttrSetCmds' refer to entries in the 'serial.ini' file that describe the actual command to be sent. The entries in the 'EquipAttrSetCmdPorts' and 'EquipAttrSetCmdAddrs' describe
- 15 which serial port the attached equipment is connected to and the address of the attached equipment (in the case that multiple pieces of equipment are attached via the same serial port). Similarly, the 'EquipAttrMonConns' entry refer to configuration entries in the 'monitor.ini' file that describe the mechanism by which the attribute is recovered from the attached equipment and the 'EquipAttrMonConnPorts' and 'EquipAttrMonConnAddrs'
- 20 describe the serial ports and addresses used for data recovery.

Hence the IC is in not actually aware of the semantics of the data values it is 'setting' or 'getting' and the mapping between the equipment and equipment attributes that the MC believes it is controlling is completely defined by the equipment controller configuration files and not equipment controller software.

The MC and IC communicate via the text format generally described above. All communication is initiated by the MC. Three request packets are currently defined: 1) a request to modify the attributes of a particular piece of equipment at a particular time in the future, 2) a request to cancel the request to modify the attributes of a particular piece of equipment, and 3) a request to return the current values of the attributes of a particular piece of equipment. Each request is normally responded to with a complementary message. In some cases, however, no response message purposely generated in order to communicate a negative response.

The request to modify the attributes of a particular piece of equipment is known as a Transmission Change Order (TCO). The format of a TCO is as follows:

TCO

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

15 Time=YYYYMMDDHHMM

Attribute1=Value1

Attribute2=Value2

When the IC receives a TCO it validates the request. The request validation includes confirming that the requested change time has not already past and that the IC configuration supports the requested modifications. The IC refers to its memory resident database of configuration data to validate request. First the IC insures that the requested equipment is identified in the configuration. It then insures, by tracing the attributes named in the request through the configuration to the commands that must be issued to insure that sufficient

configuration information is present to form the required commands. Finally it checks to see if the equipment is currently responding to commands.

If an error is detected such that the request cannot be supported by the configuration, a response is returned to the MC identifying the offending request data. For example, if a request contained an equipment identification that did not exactly match an entry in the 'equipctl.ini' file or if an attribute name did not exactly match one of the legitimate attributes named in the 'equipctl.ini' file, a response would be sent indicating why the TCO was invalid and implicitly indicating that the request would not be implemented. Further, if a legitimate attribute is named, but the equipment controller finds that either no serial command is referenced or that the referenced serial command is not configured, the IC will also send a similar response indicating why the request cannot be implemented. Validation of the parameter values may also be accomplished in a similar technique.

If the request is otherwise correct, but the equipment is currently not responding to serial commands, no response is purposely generated, indicating that no problem was detected in the request but that since no acknowledgment was sent, the request will not be implemented at the specified time.

Else an acknowledgment is returned to the MC indicating that unless otherwise instructed, the IC will perform the requested configuration change at the requested time.

The request to cancel the modification of the attributes of a particular piece of equipment is known as a Abort Message (ABRT). The format of an ABRT is as follows:

ABRT

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

The IC will remove the outstanding command set to be issued to the specified equipment if any command is queued and will send an acknowledgment to the MC indicating it has done so. If, at the time of receipt, no command is outstanding, the IC will respond with a message
5 indicating that no command was found.

Figure 13 depicts a flow chart of a transmission plan execution. Initially, the system may have an unscheduled transmission (1302). The transmission plan may be assigned an execution time (1304). The transmission plan may be propagated to the network to place the plan onto a pending status (1306). After all of the TCO's required to implement the
10 transmission plan have acknowledged the command, the transmission plan is ready for execution (1308). At the transmission plan execution time (1310) the plan began the start sequence. After the MC confirms that all TCO's have been confirmed, *e.g.*, so that the MC does not issue an abort command, the transmission plan goes active (1312).

The system then begins normal operation on the new transmission plan and the system
15 begins collecting data again on link usage (1316). Special transmission plans, *e.g.*, transmission plans that are not recurring, are not re-scheduled (1318).

Figure 14 depicts a bandwidth allocation request. This control loop may execute at the MC. The system may receive a request for bandwidth 1402 from the Bandwidth administrator or an IC. The request may be an unscheduled network event 1404. The request
20 for bandwidth is decoded and scheduled for execution 1406. The execution schedule may be for immediate execution or for a scheduled deployment. The appropriate TCO may be sent from the MC to the appropriate IC to propagate the transmission plan and to put the plan into the ready state 1408. The transmission plan then waits for its execution time. When the transmission plan execution time arrives (1410) the MC confirms that the TCO's were

confirmed by the ICs. If the TCO's were confirmed, the plan goes active (1412) at the predetermined time. the system has thereby fulfilled (1414) the bandwidth request.

The IC may implement a control loop similar to that shown and described above. The IC may confirm that a channel is available within the present transmission plan 1406 and immediately execute the new transmission plan 1408, 1410 and 1412. The IC may then notify the MC 1402 of the unscheduled 1404 transmission plan. The MC may then proceed as described above to propagate and deploy the new plan.

Figure 5 depicts the inter-process communication between the MC 502 and ICs (506) and 542. MC commands are sent via the UDP/IP link 504 from the control component 503 to the equipment control component 514. The equipment controller 514 then maps the generic network commands from the MC to specific commands (discussed above) for output (512) to the managed equipment (510). The equipment controller (514) may lose the command event (524). The IC may also denote the command event on the local display 530.

The system may receive alarm and other network messages that may effect the network management display 518 via the TCP/IP connection 516. Equipment controller 514 may connect to the display controller 518 when the equipment controller 514 receives an alarm condition from the network equipment (510,520) via command links (512, 522). The event logger (534) may receive network audits and network events from the IC 506 equipment controller (514) via UDP/IP link 532. As provided above, each of the communication processes on Figure 5 may be interpret or poll driven.

The IC may also denote the command event on the local display 530.

The system may receive alarm and other network messages that may effect the network management display 518 via the TCP/IP connection (516). Equipment controller (514) may connect to the display controller (518) when the equipment controller 514 receives an alarm condition from the network equipment (510,520) via command links (512, 522).

The event logger (534) may receive network audits and network events from the IC 506 equipment controller (514) via UDP/IP link (532). As provided above, each of the communication processes on Figure 5 may be interrupt or poll driven.

5 Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. The specification and examples should be considered exemplary only. The scope of the invention is only limited by the claims appended hereto.

Therefore we claim:

1. A system for controlling a network of communication terminal comprising:
a management component;
5 an implementation component, said implementation component in communication with said management component to receive at least one transmission plan, said transmission plan containing a scheduled implementation time, said implementation component receiving said transmission plan, decoding an implementation time for said transmission plan and outputting
10 command to network component at said implementation time to implement said transmission plan.
2. A method for managing a communication network with an adaptive transmission plan comprising:
analyzing network bandwidth allocation over a predetermined period of time;
15 determining a transmission plan to accommodate, at least in part, the results of said analysis of said network bandwidth allocation;
deploying said transmission plan to a plurality of network component to implement said transmission plan; and
analyzing network bandwidth allocation short falls over a predetermined period of time to
20 identify a transmission plan that accommodates bandwidth demands.

3. A method for facilitating network management in a multiple vender network comprising:

receiving a generic network command at an implement component;

5 decoding said generic network command;

translating said decoded generic network command to specific commands for a particular device through a text based file that contains text strings of specific device commands;

and

outputting said translated commands to said particular network device.

Figure 1.

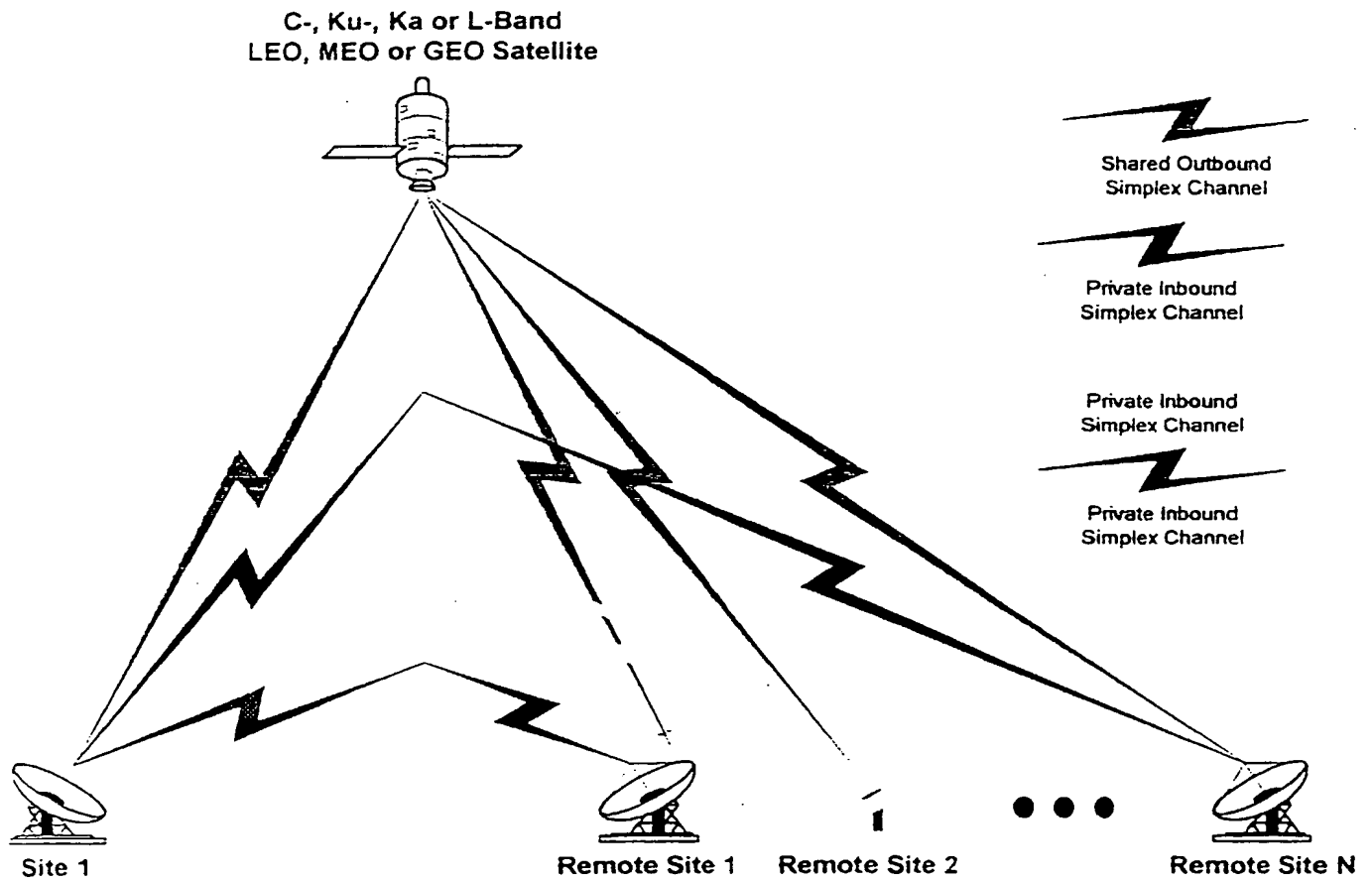
**BEST NETWORK
STAR TOPOLOGY**

Figure 2.

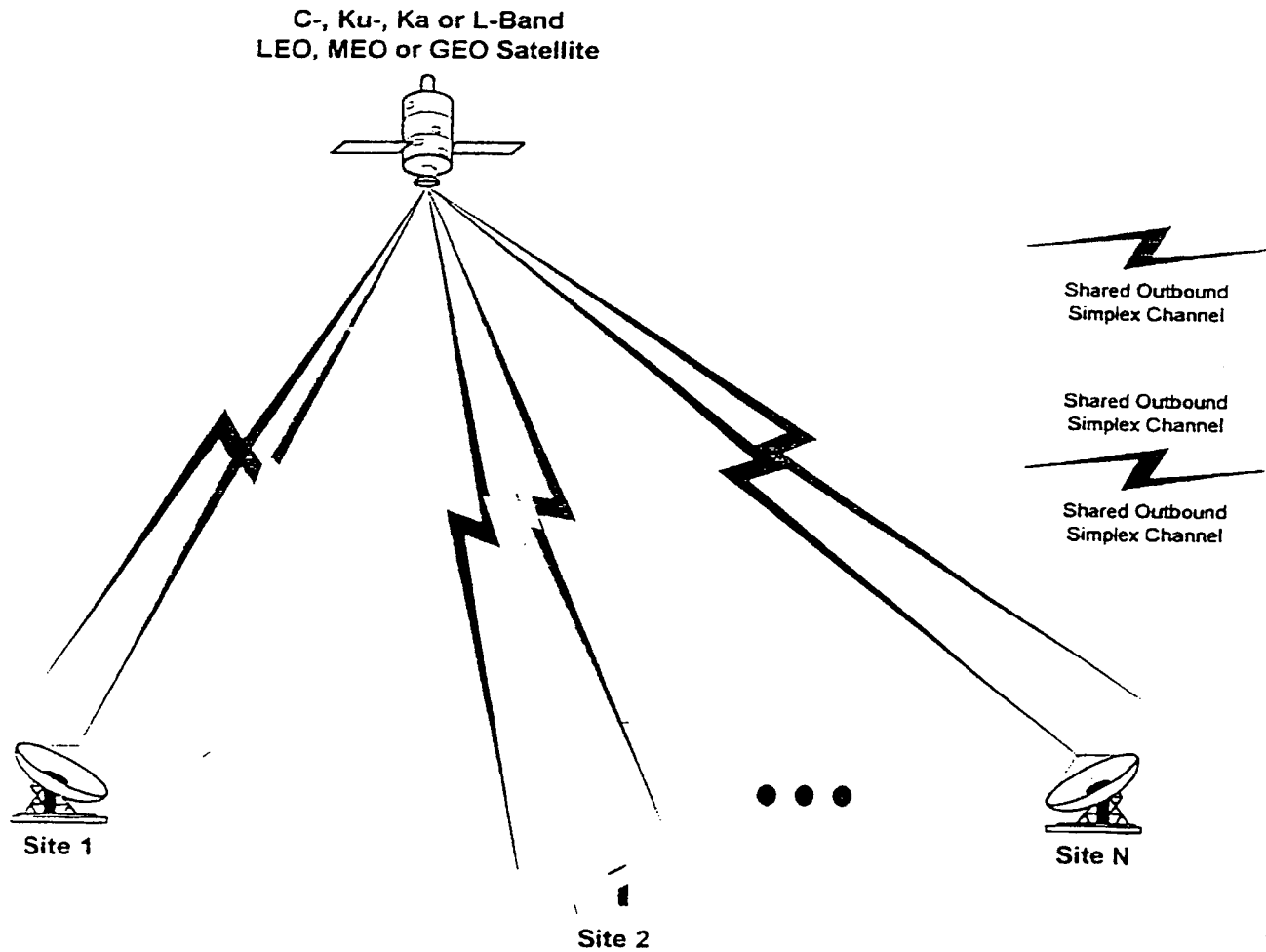
**BEST NETWORK
MESH TOPOLOGY**

Figure 3.

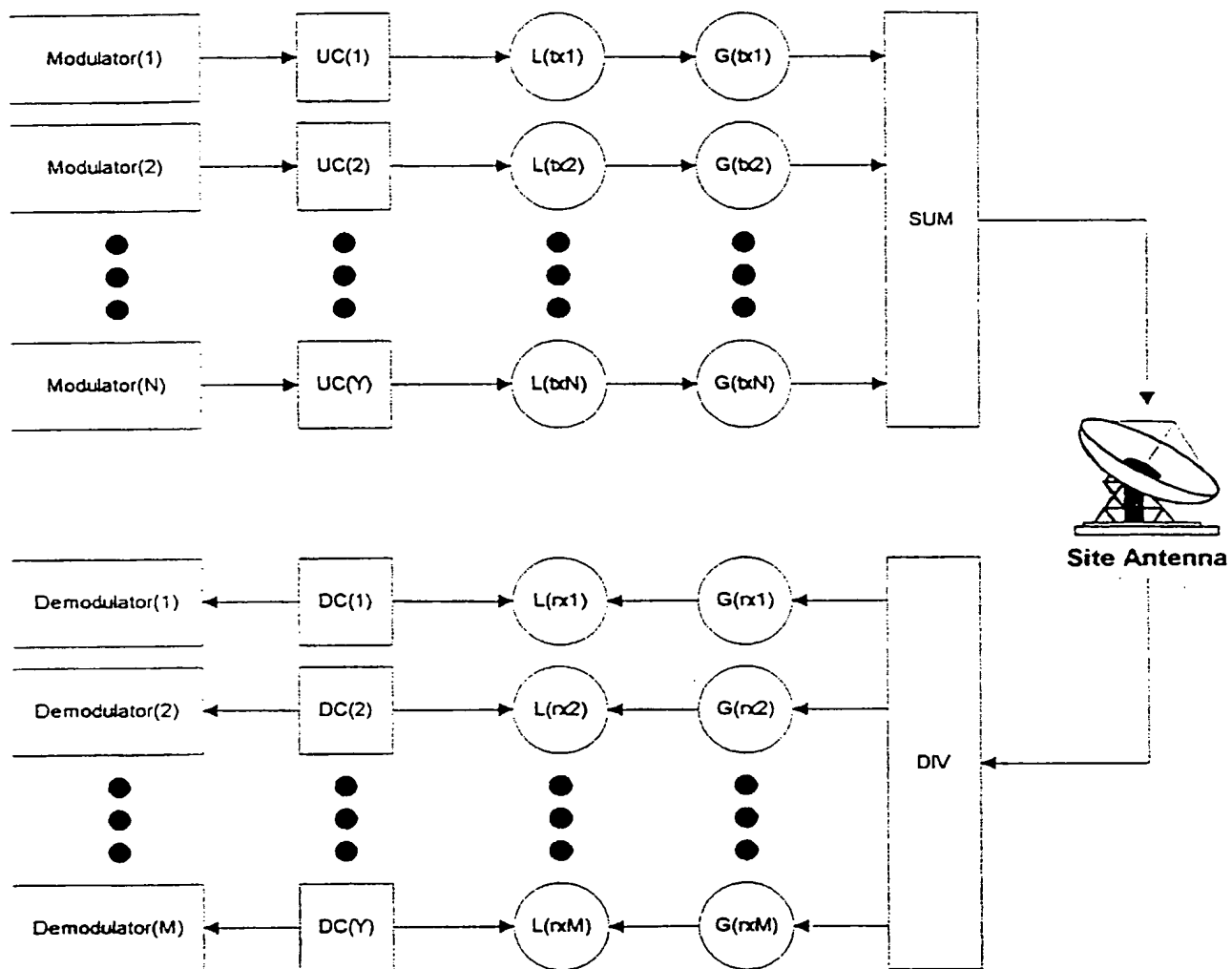
**BEST NETWORK SITE
TRANSMISSION EQUIPMENT MODEL**

Figure 4.

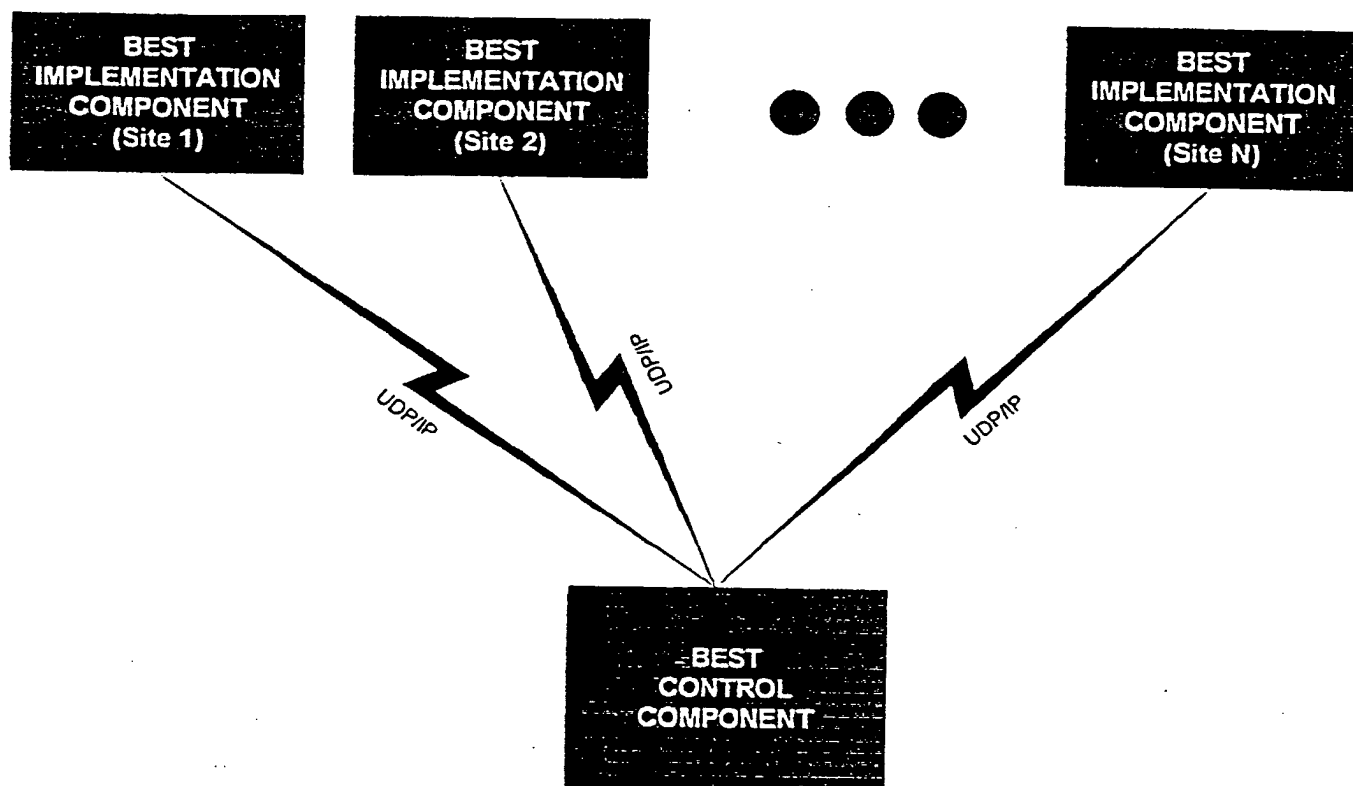
BEST SOFTWARE COMPONENTS

Figure 5.

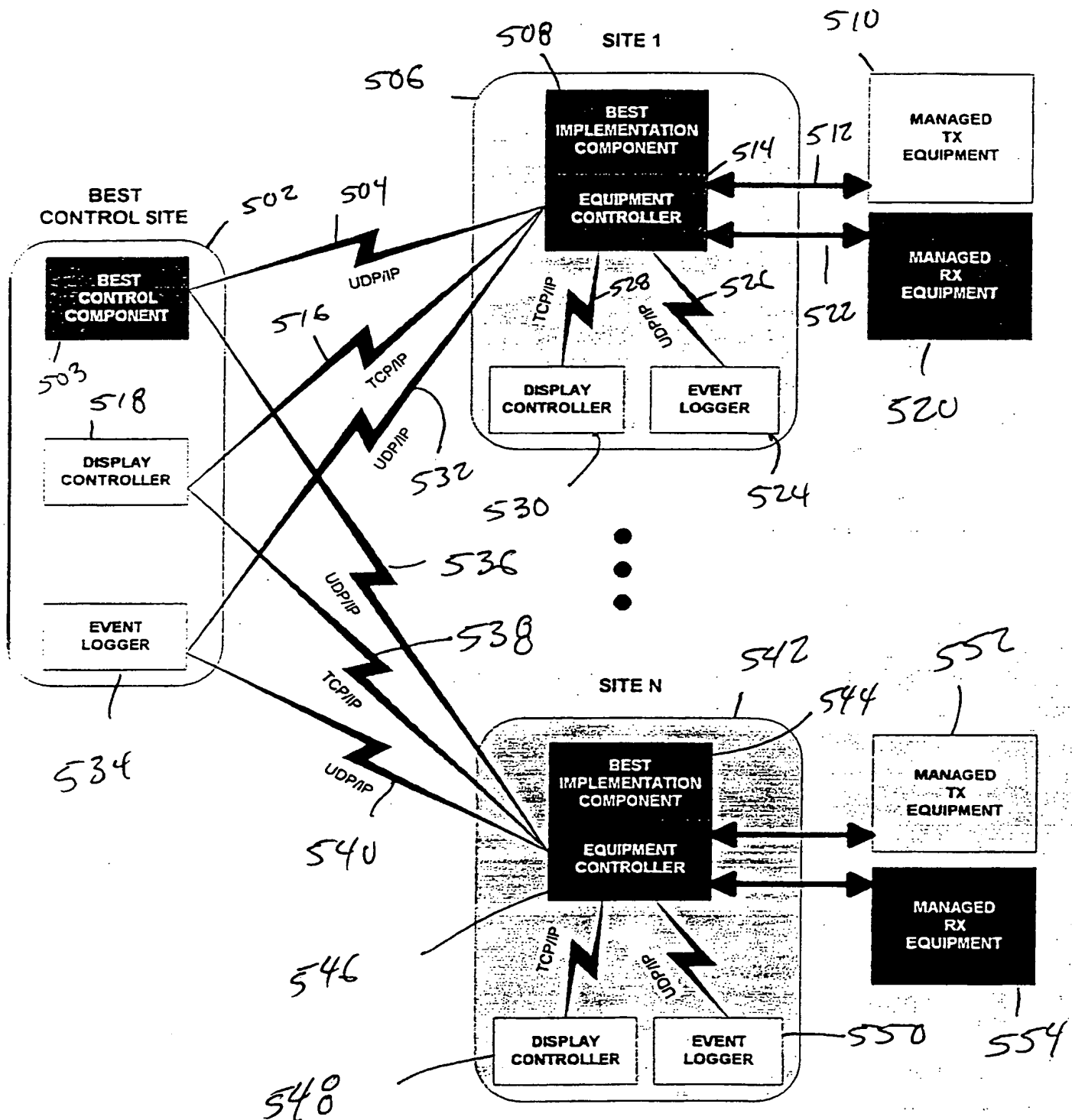
BEST/NMS DISTRIBUTED
SOFTWARE COMPONENTS

Figure 6.

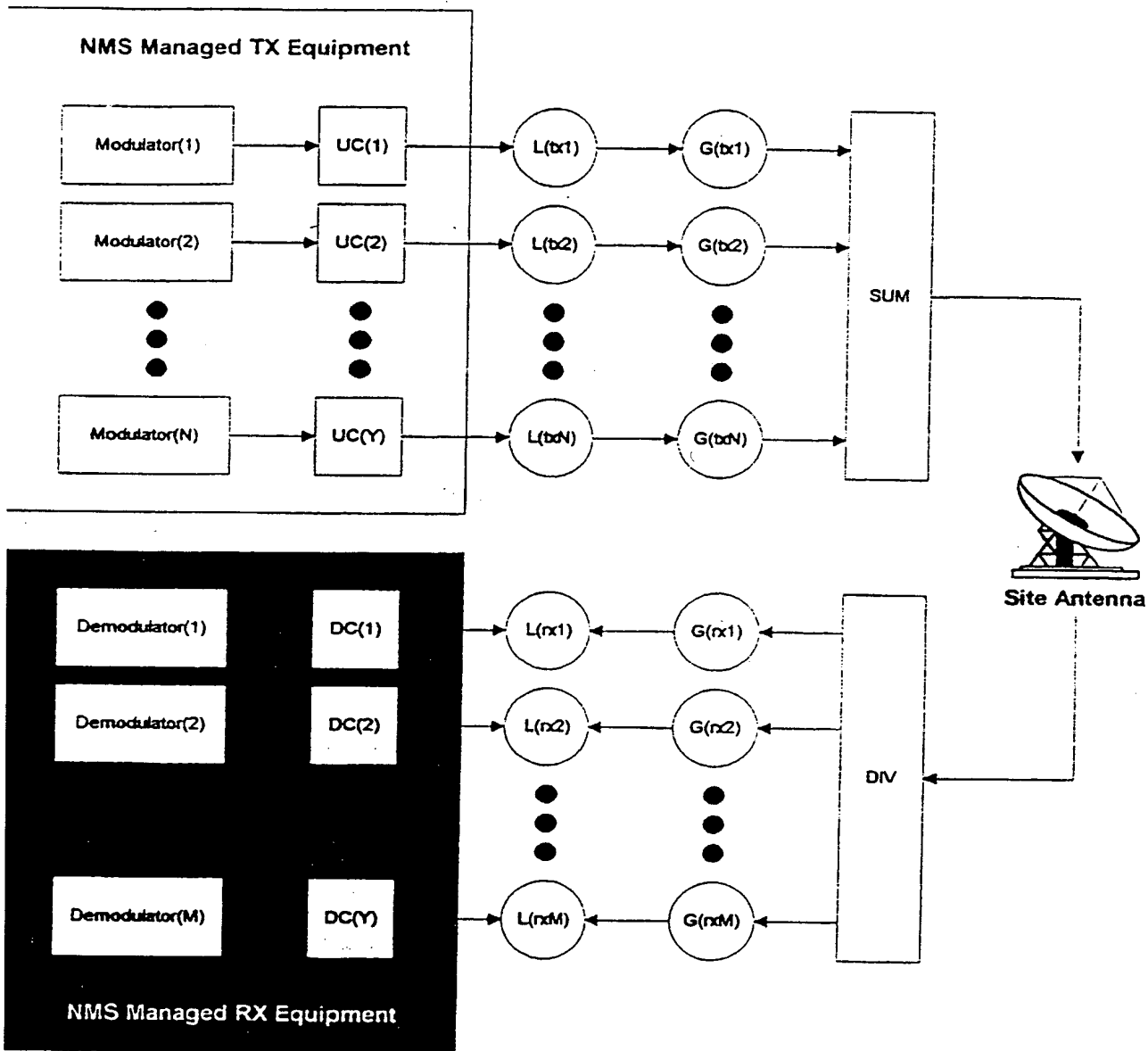
**BEST NETWORK SITE
NMS MANAGED EQUIPMENT**

Figure 7.

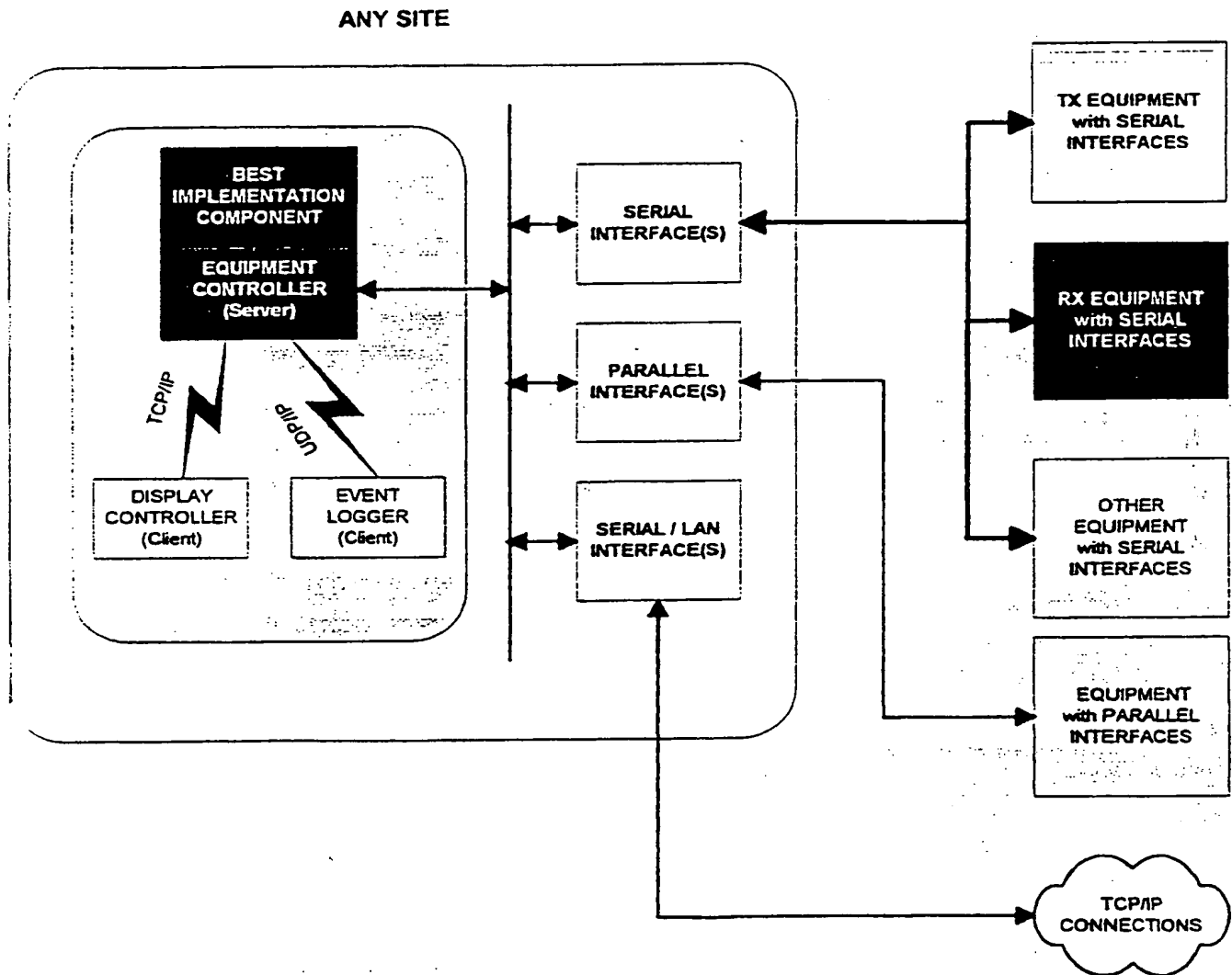
BEST EQUIPMENT CONTROLLER ENVIRONMENT

Figure 8.

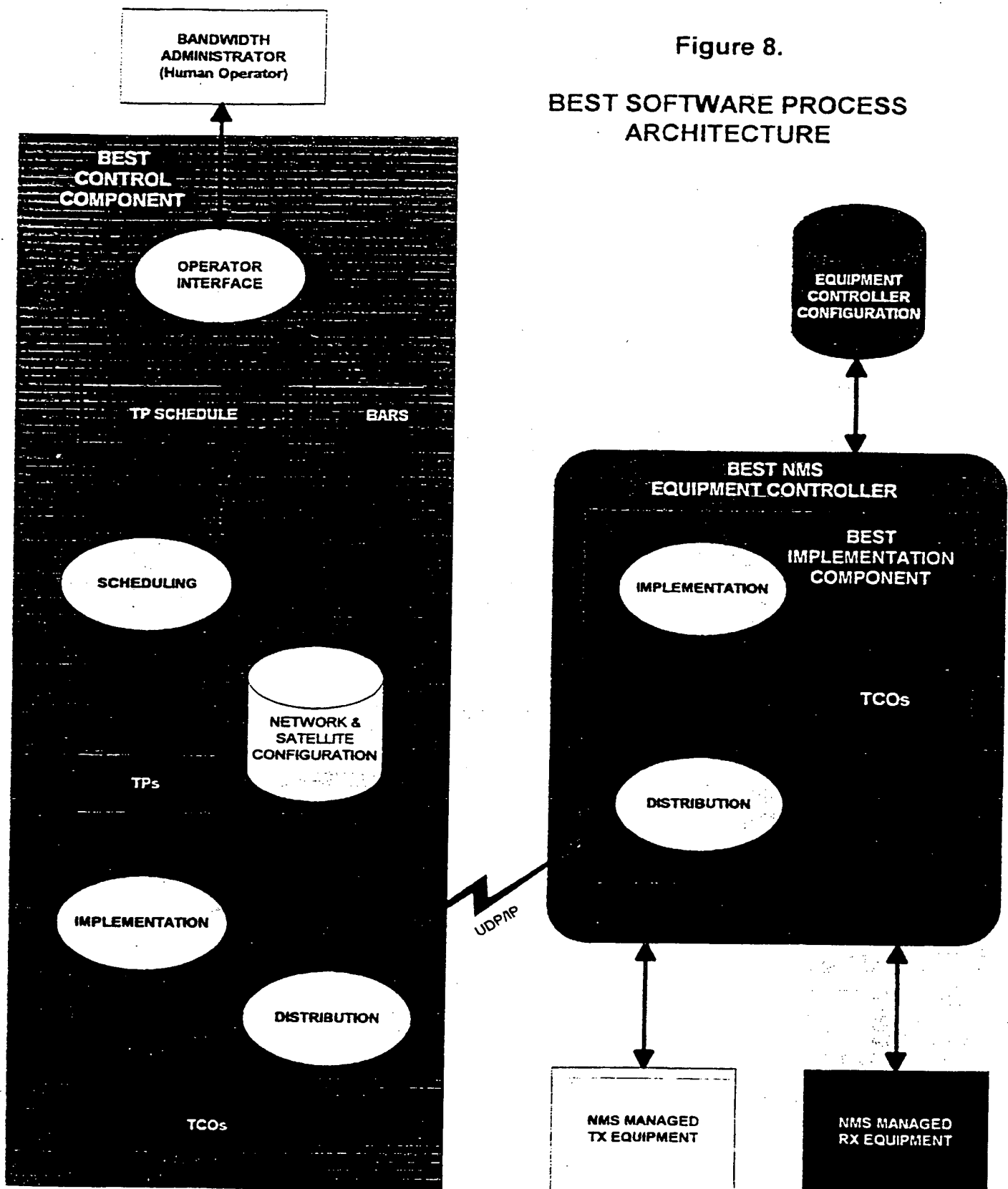
BEST SOFTWARE PROCESS
ARCHITECTURE

Figure 9.

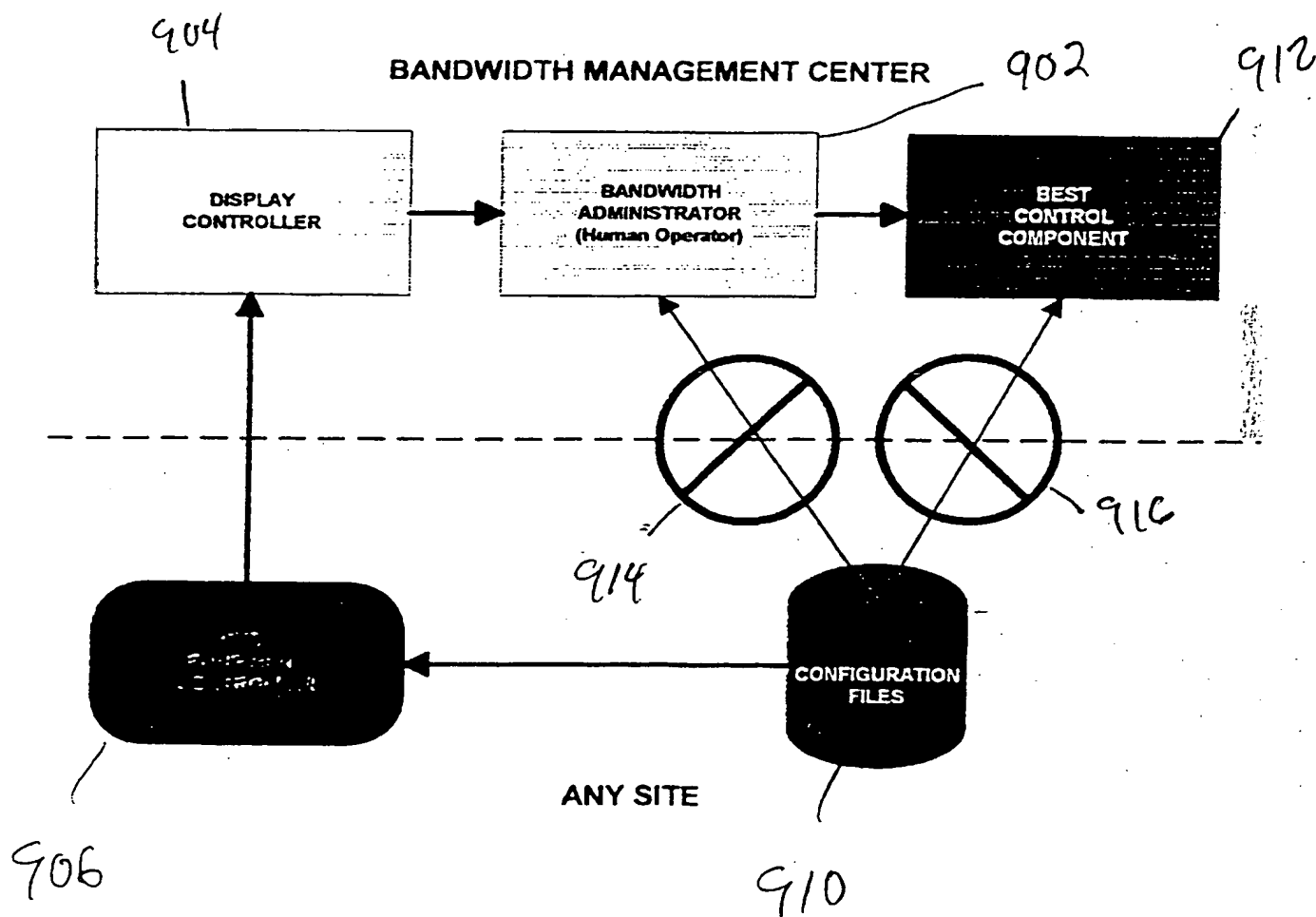
**BEST HARDWARE CONFIGURATION
INFORMATION FLOW**

Figure 10.

BEST TRANSMISSION PLAN CONCEPTS

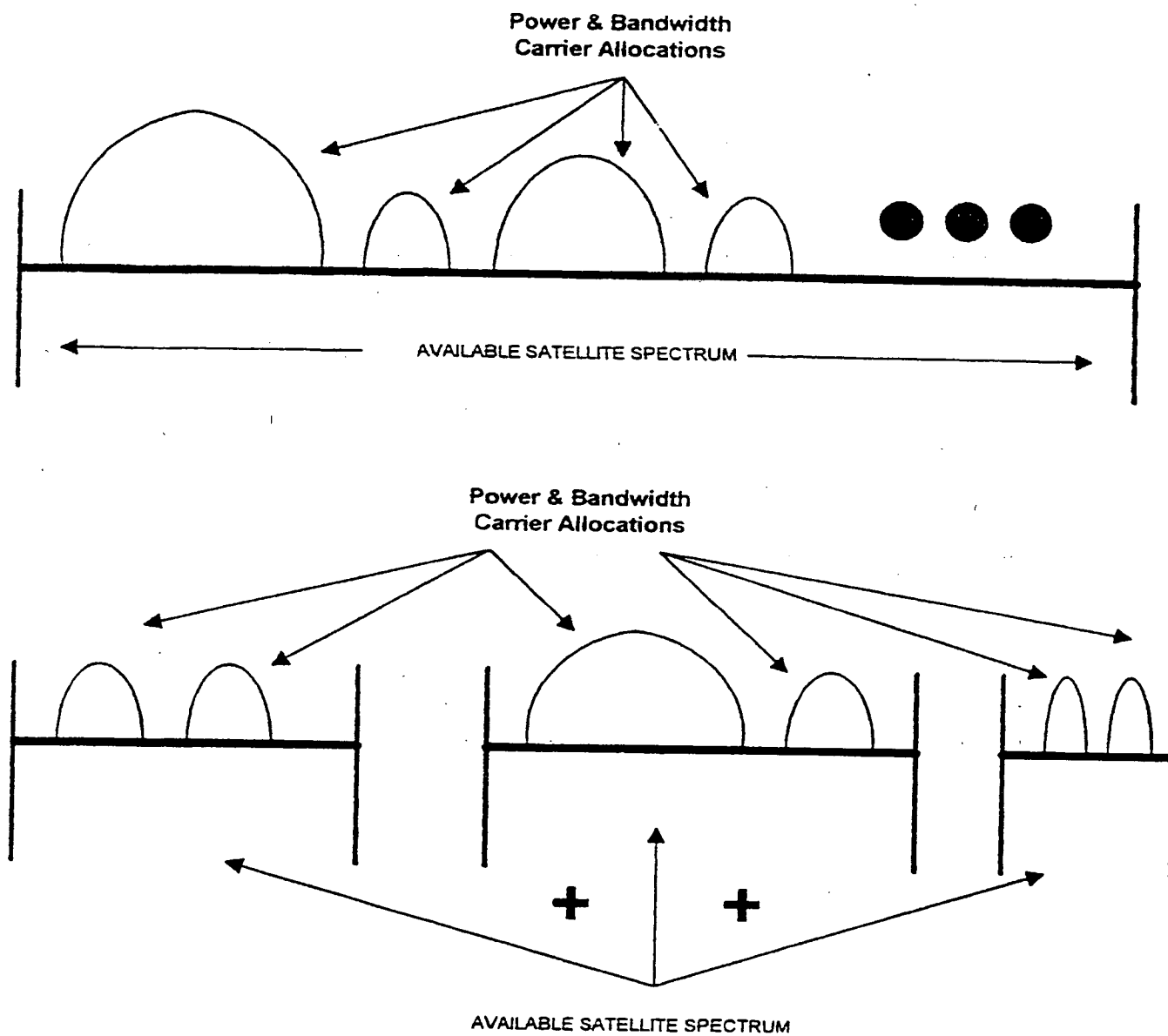


Figure 11.

BEST EXAMPLE TRANSMISSION PLAN SCHEDULE

	Time 0	Time 0 + 6 hours	Time 0 + 12 hours	Time 0 + 18 hours
Monday	Transmission Plan #1	Transmission Plan #2	Transmission Plan #3	Transmission Plan #4
Tuesday	Transmission Plan #5	Transmission Plan #6	Transmission Plan #7	Transmission Plan #8
Wednesday	Transmission Plan #9	Transmission Plan #10	Transmission Plan #11	Transmission Plan #12
Thursday	Transmission Plan #13	Transmission Plan #14	Transmission Plan #15	Transmission Plan #16
Friday	Transmission Plan #17	Transmission Plan #18	Transmission Plan #19	Transmission Plan #20
Saturday	Transmission Plan #21	Transmission Plan #22	Transmission Plan #23	Transmission Plan #24
Sunday	Transmission Plan #25	Transmission Plan #26	Transmission Plan #27	Transmission Plan #28

Figure 12.

**BEST EXAMPLE
MONDAY TRANSMISSION PLANS**

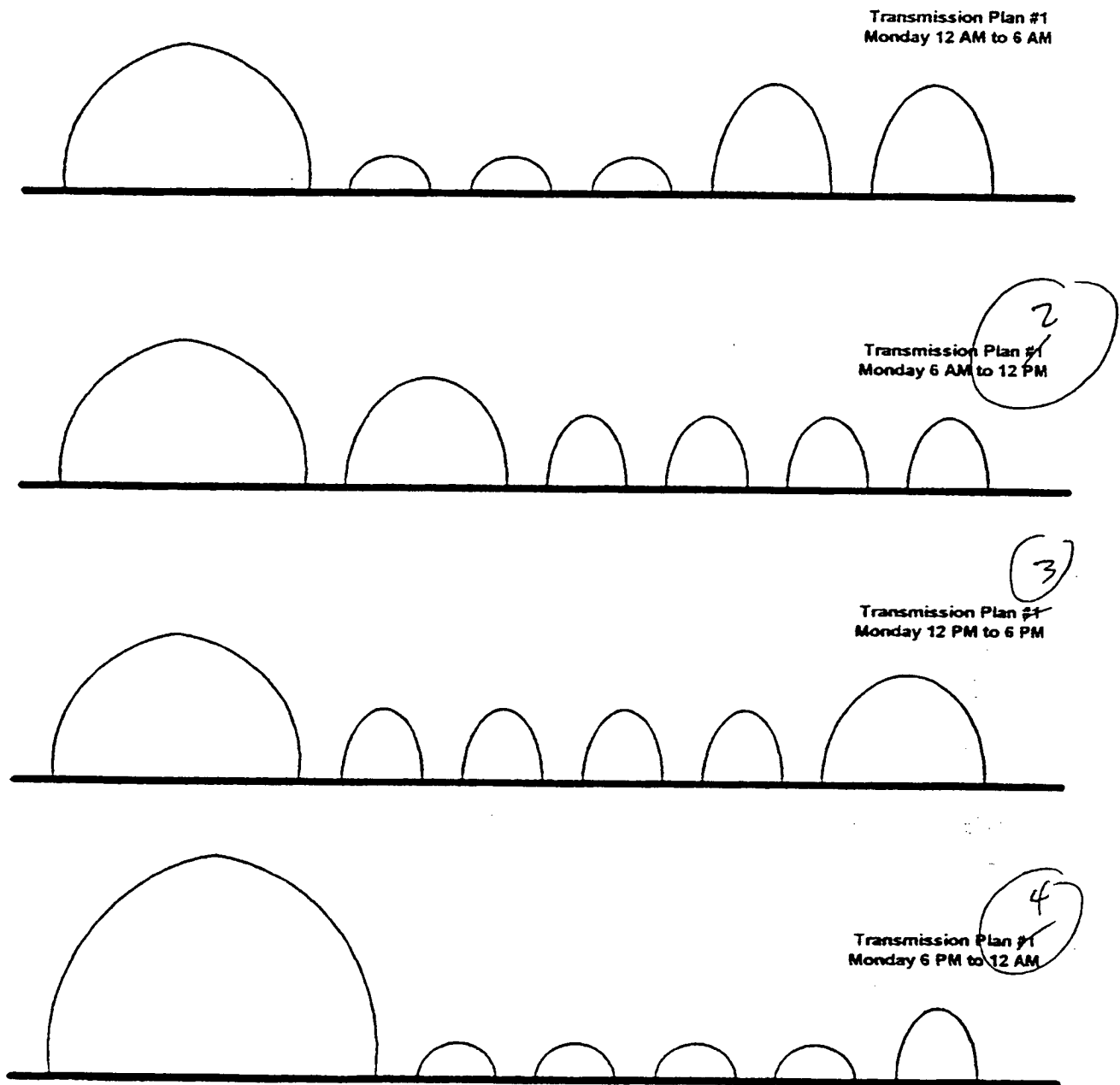


Figure 13.

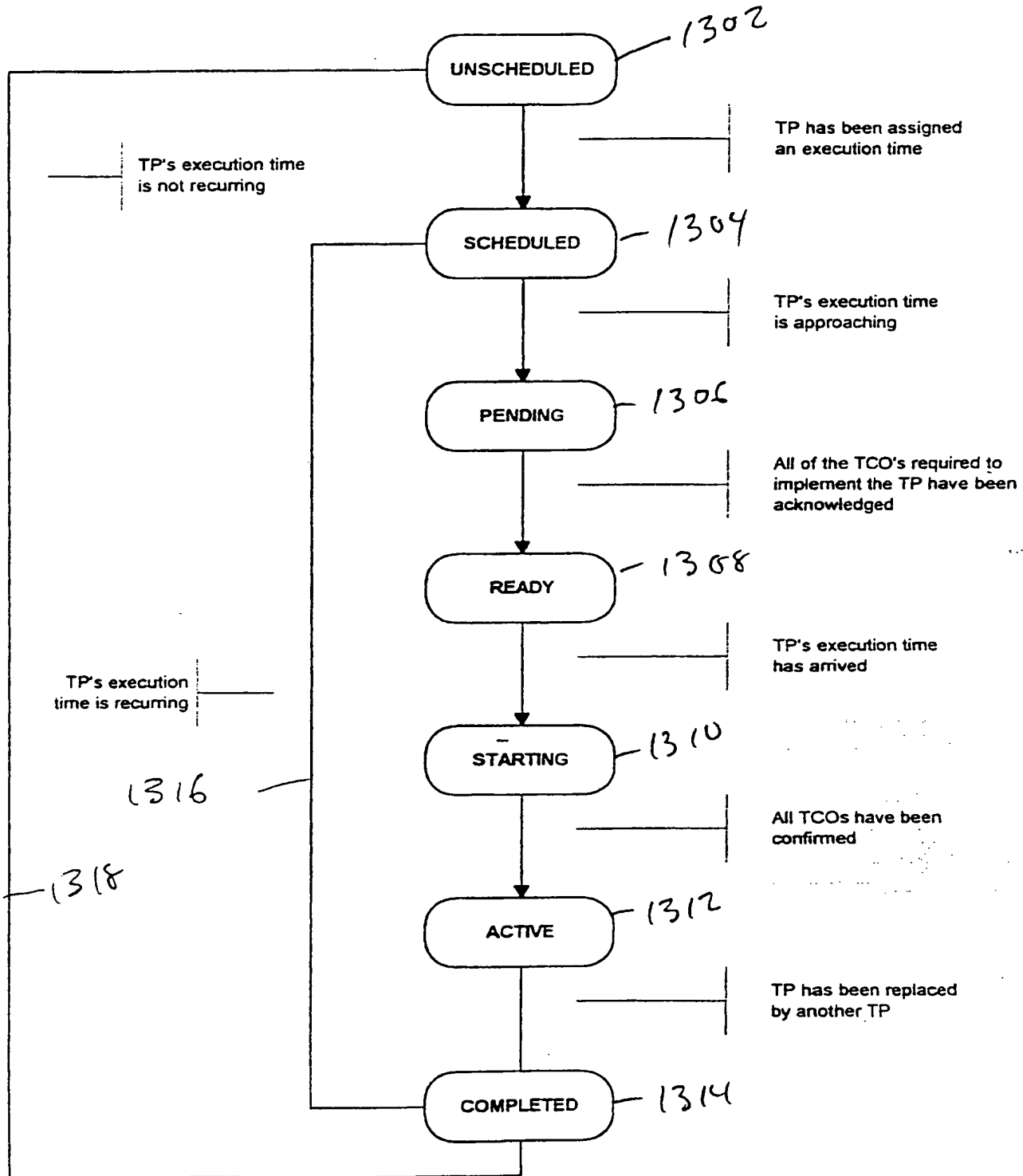
**BEST
TRANSMISSION PLAN EXECUTION**

Figure 14.

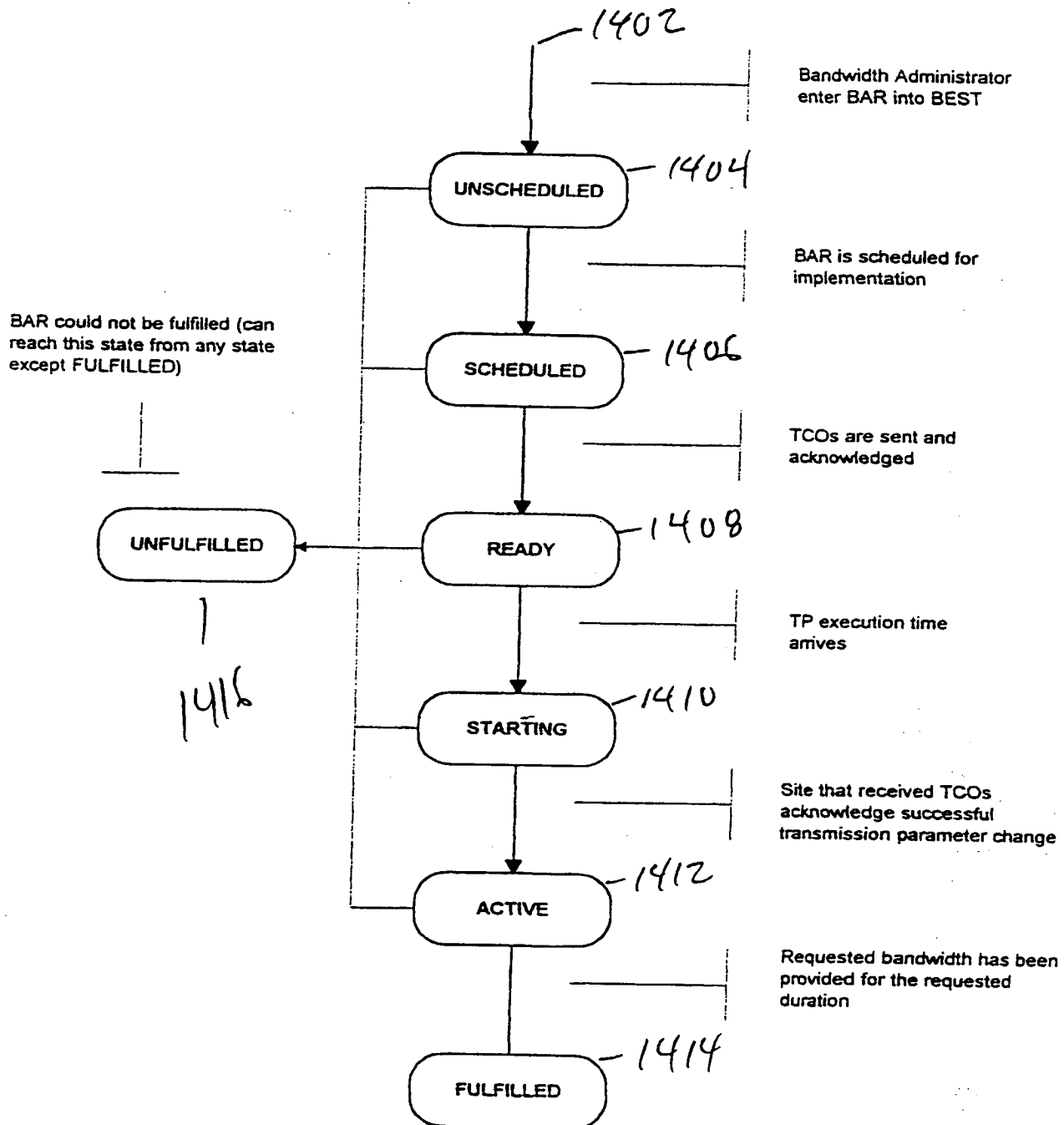
**BEST
BANDWIDTH ALLOCATION REQUEST
EXECUTION**

Figure 15.

UDP Datagram Format

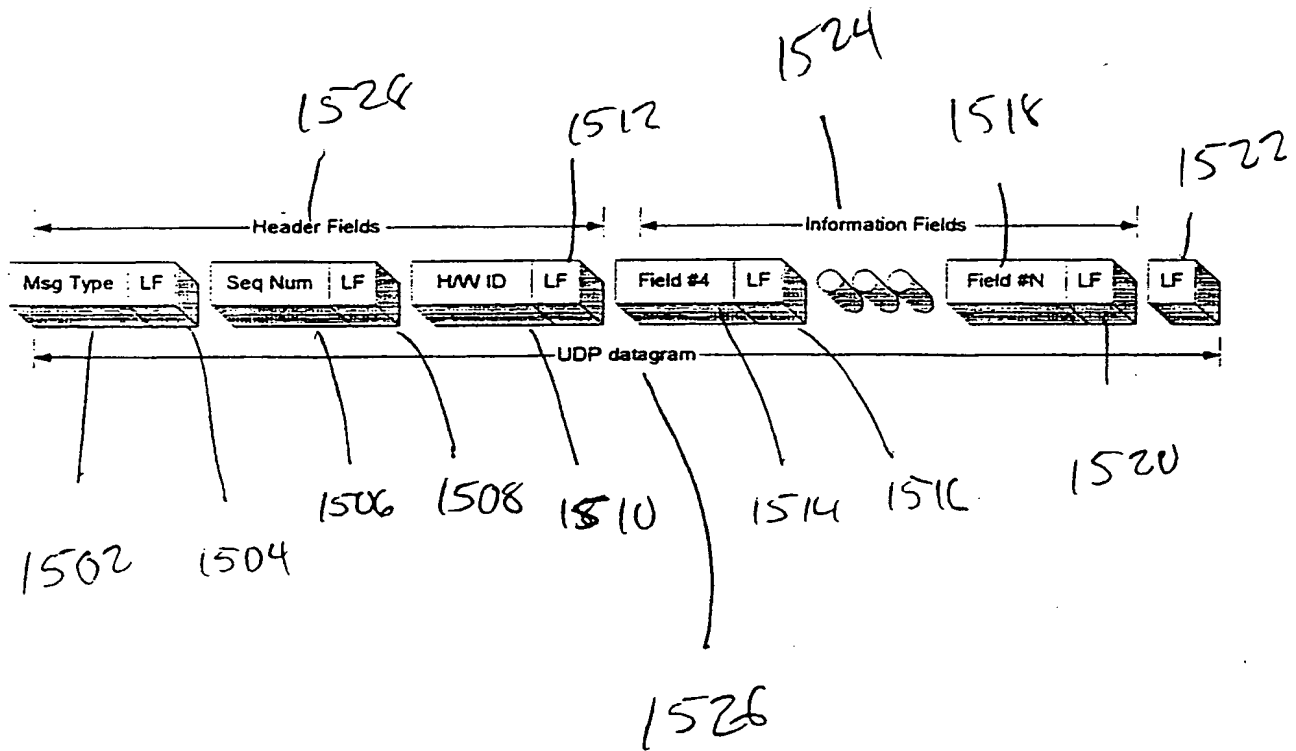


Figure TBD.

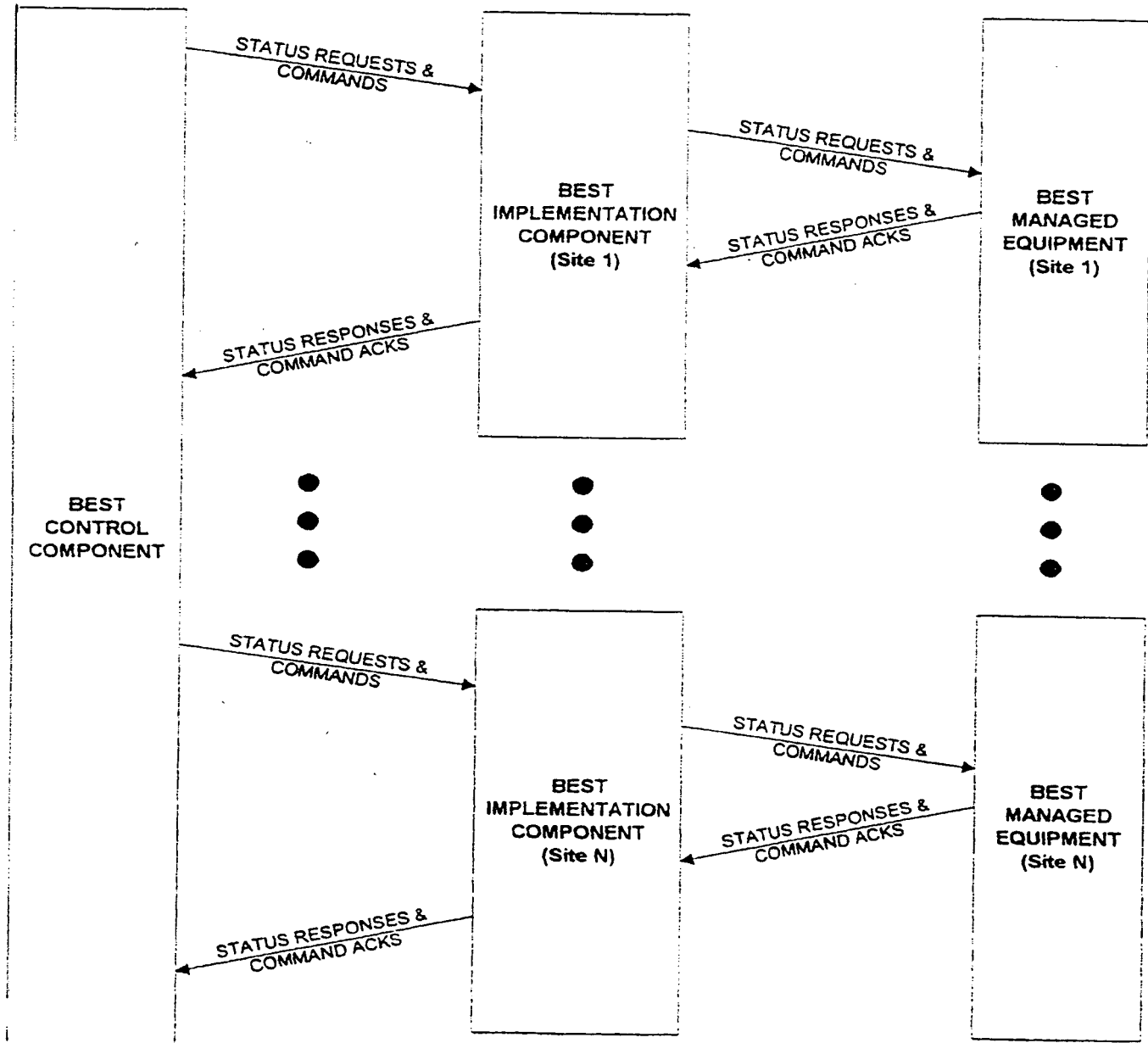
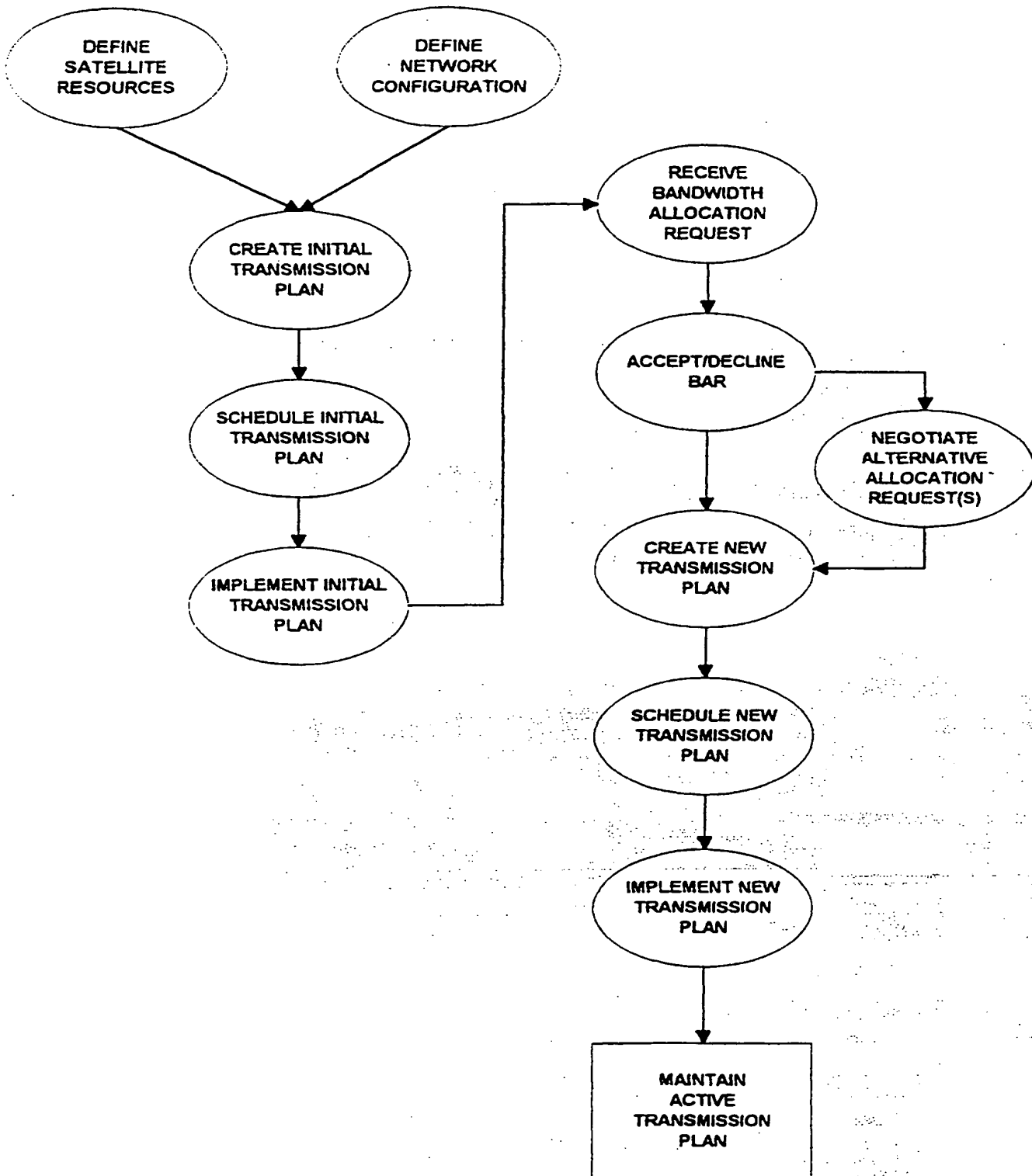
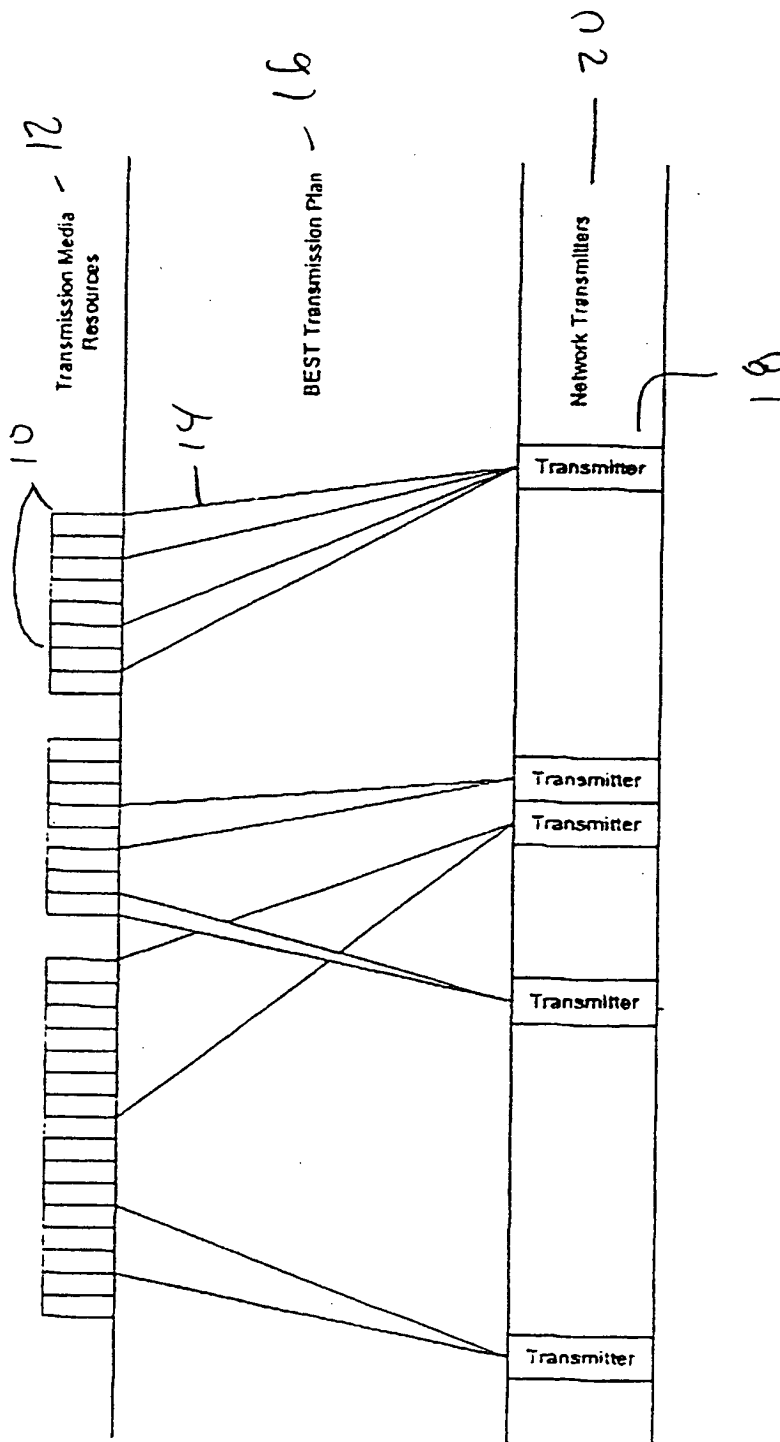
BEST REQUEST/COMMAND FLOW

Figure TBD.

BEST BASIC OPERATION



BEST Transmission Plan Fig. 18



A BEST Transmission Plan allocates the transmission media resources among the transmitters in a network.

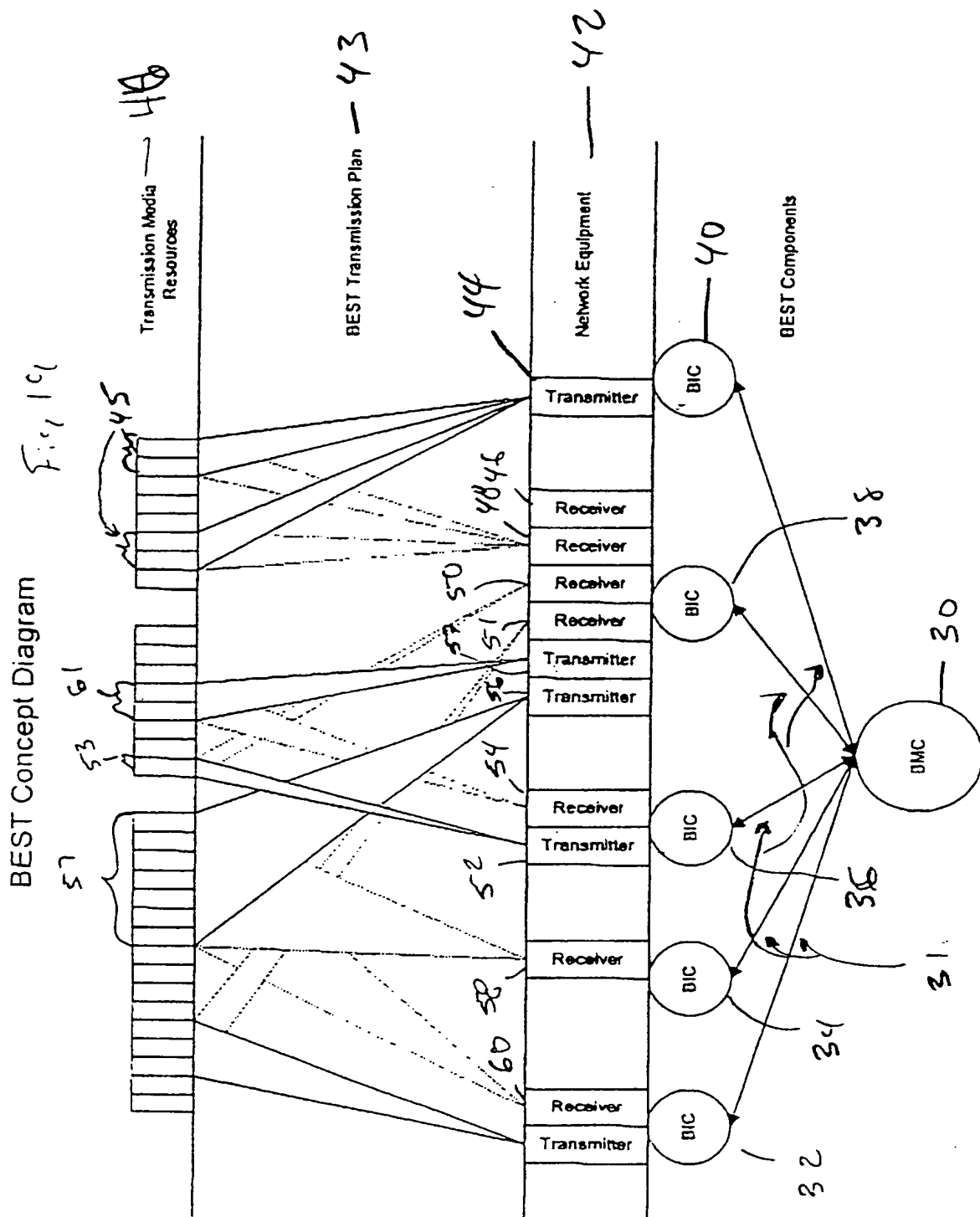
Only transmitters are specified in a BEST Transmission Plan because only transmitters use transmission media resources.

The BMC automatically configures network receivers based on the transmitter the receiver is receiving.

The BMC implements a BEST Transmission Plan by sending commands to the DBCs controlling the transmitters and receivers in a network.

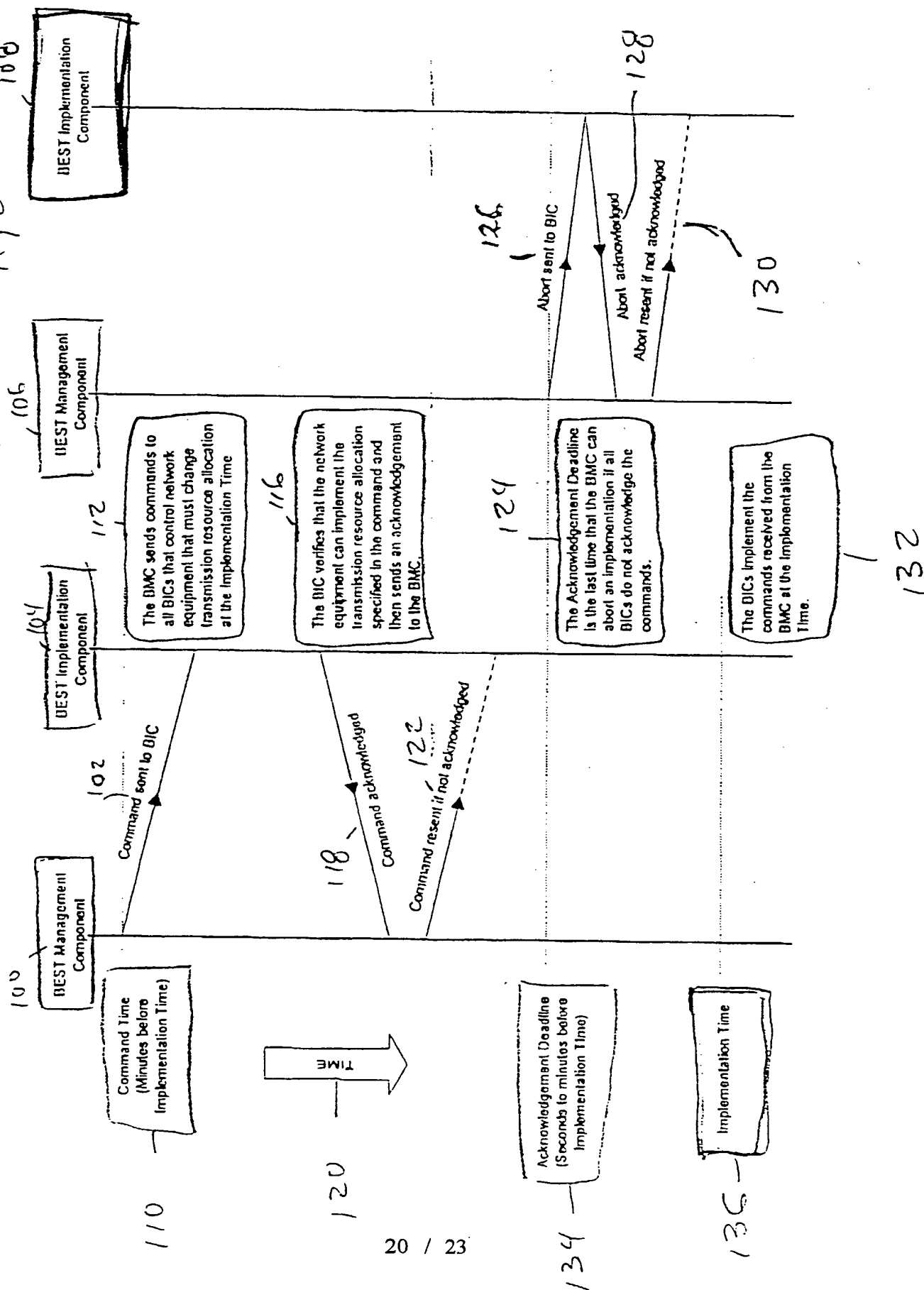
Multiple BEST Transmission Plans can be defined.

The BMC maintains a schedule of BEST Transmission Plan implementations.

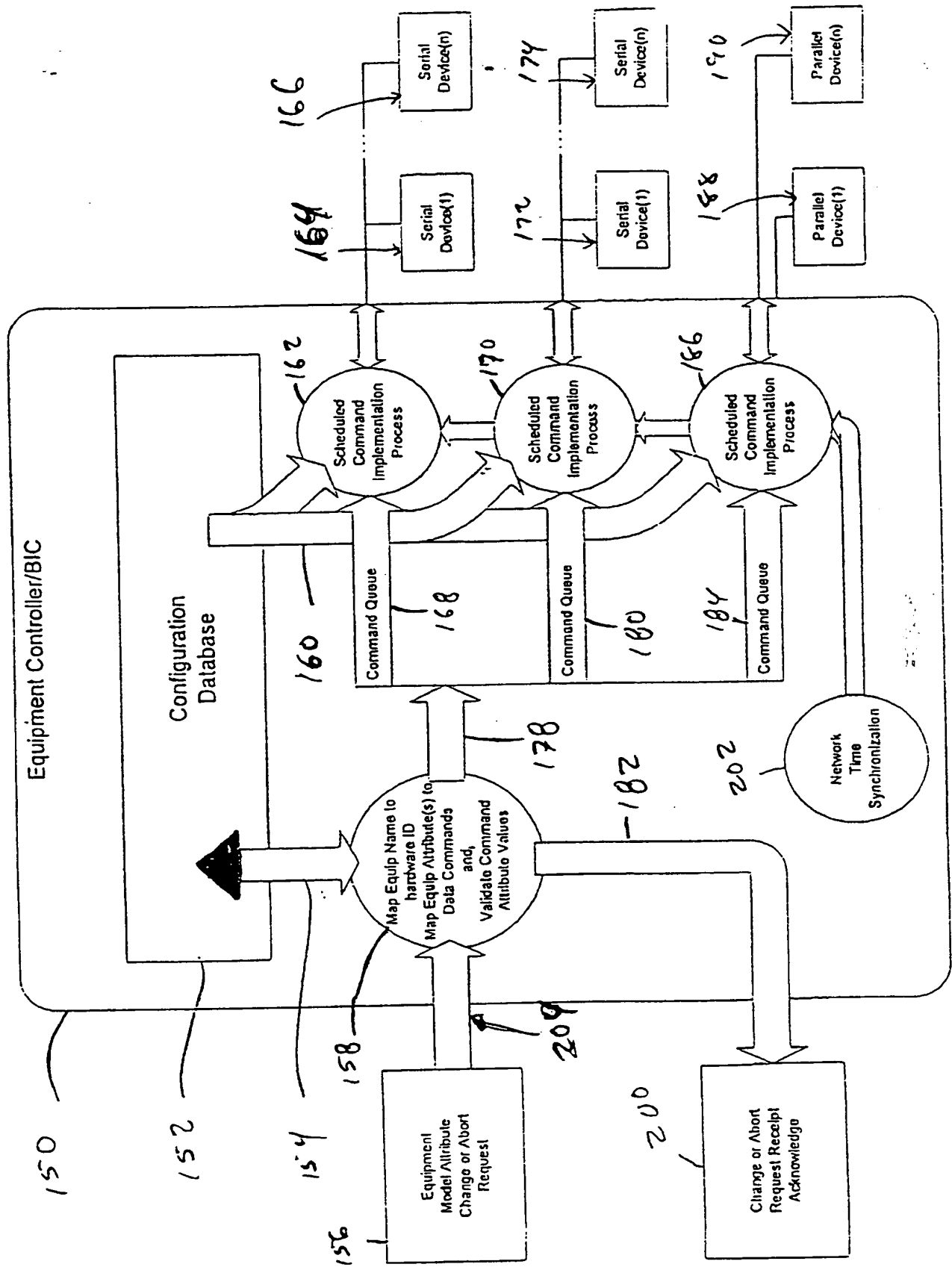


BEST Transmission Plan Implementation

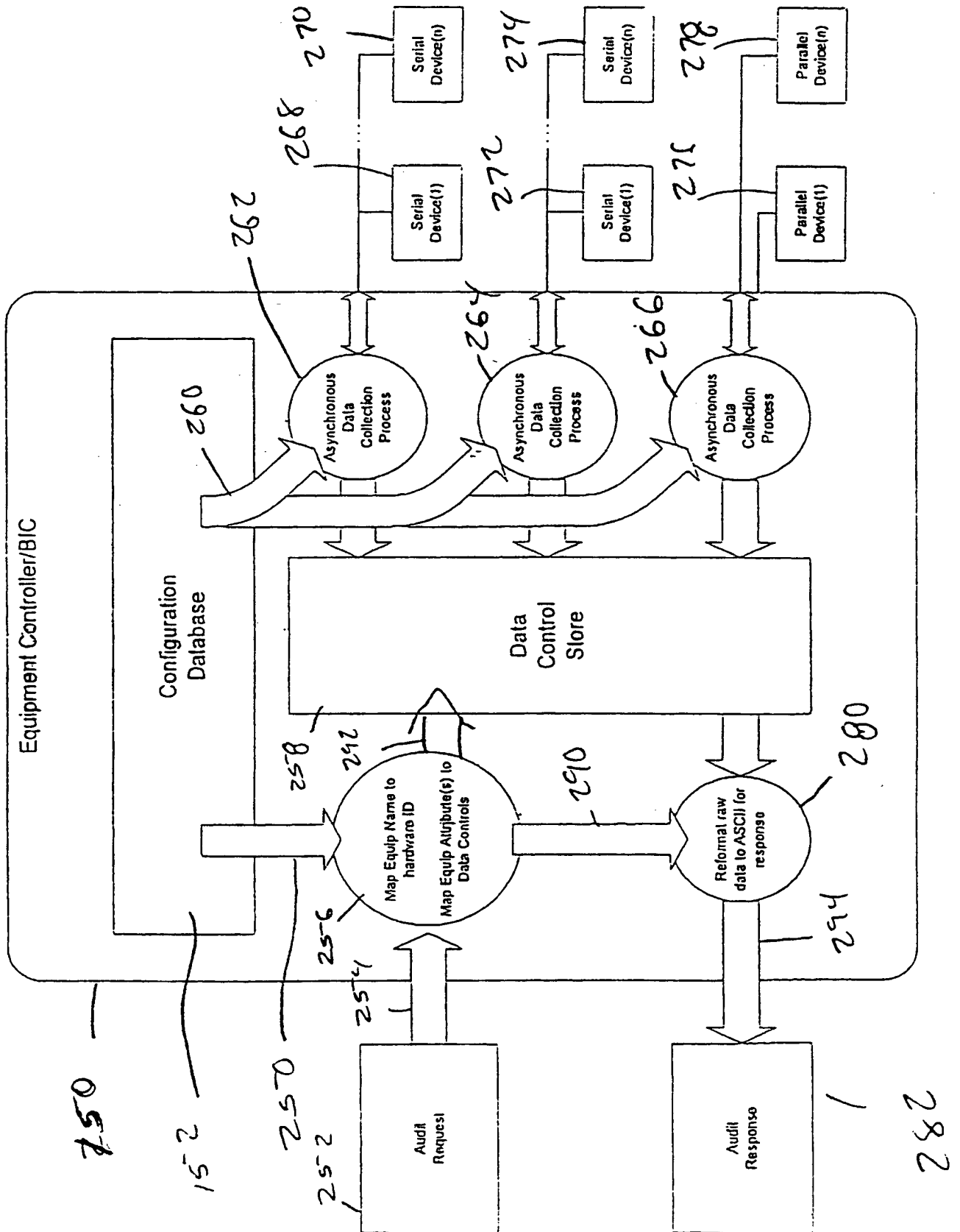
Feb 20

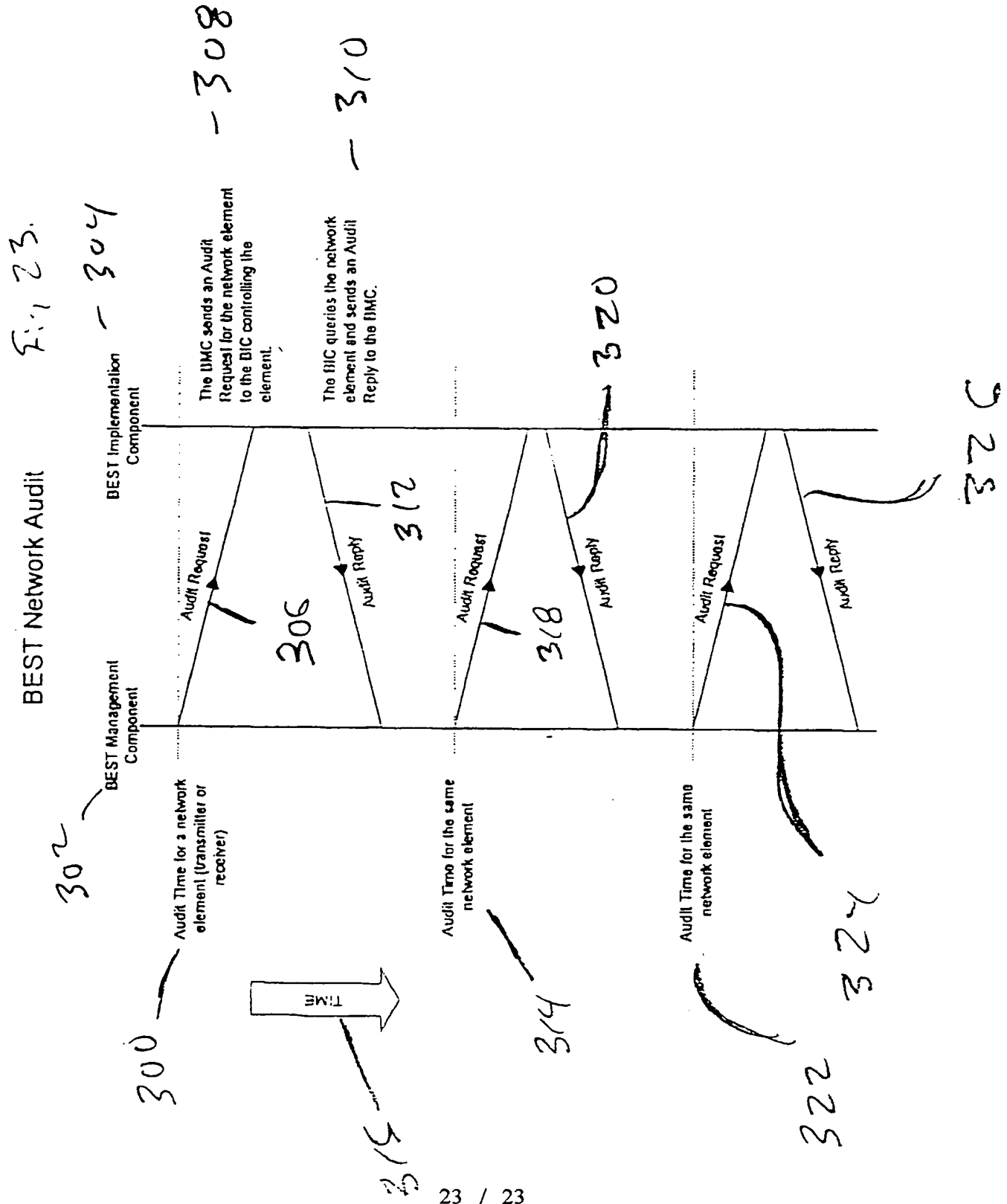


BEST Network Command Processing



BEST Network Audit Processing
Fig. 22





INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01317

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04B 7/00; H04J 1/16

US CL : 370/252, 319, 468

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/252, 254, 255, 315, 319, 341, 468

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,689,568 A (LABORDE) 18 November 1997, col. 1, line 45 to col. 2, line 15.	1-3
A	US 5,533,023 A (OHLSON et al) 02 July 1996, abstract.	1-3
A	US 5,592,470 A (RUDRAPATNA et al) 07 January 1997, abstract.	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	
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Date of the actual completion of the international search 28 MARCH 1999	Date of mailing of the international search report 03 MAY 1999
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(30) Priority Data: 60/072,339 23 January 1998 (23.01.98) US			
(71) Applicant: INNOVATIVE COMMUNICATIONS TECHNOLOGIES, INC. [US/US]; 9201 Gaither Road, Gaithersburg, MD 20877 (US).			
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(74) Agents: WOOLSTON, Thomas, G. et al.; Hunton & Williams, Suite 1200, 1900 K Street, N.W., Washington, DC 20006-1109 (US).			

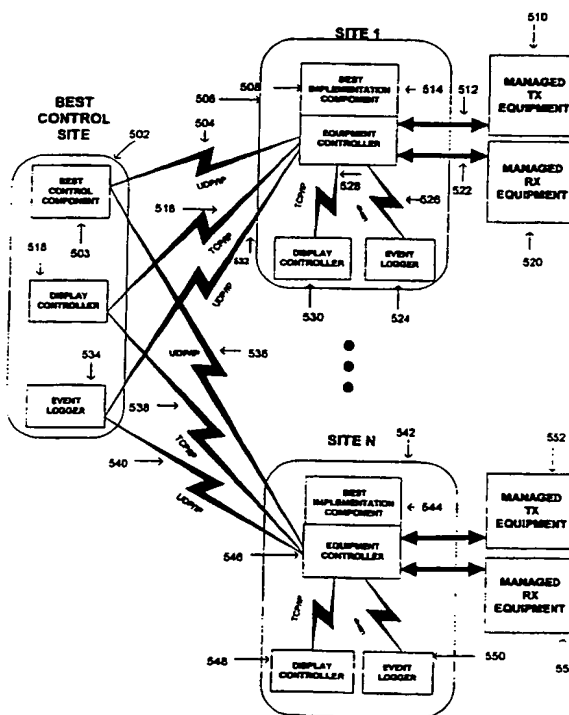
Published

With international search report.

(54) Title: CAPACITY ALLOCATION SYSTEM USING SEMI-AUTONOMOUS NETWORK ELEMENTS TO IMPLEMENT AND CONTROL A TRANSMISSION SCHEDULE

(57) Abstract

A system for controlling a network of communication terminals (510, 520, 552, 554) with a management component (503) and an implementation component (508, 544), said implementation component (508, 544) in communication with said management component (503) to receive at least one transmission plan, said transmission plan containing a scheduled implementation time, said implementation component (508, 544) receiving said transmission plan, decoding an implementation time for said transmission plan and outputting command to network component at said implementation time to implement said transmission plan.

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**CAPACITY ALLOCATION SYSTEM USING
SEMI-AUTONOMOUS NETWORK ELEMENTS TO
IMPLEMENT AND CONTROL A TRANSMISSION SCHEDULE**

FIELD OF THE INVENTION

This invention relates to communication methods and apparatus for providing network management, bandwidth and path control in a heterogeneous network that may be composed of multiple vendor equipment and transmission
5 paths. More specifically, the communication system concerns semi-autonomous implementation components within a management hierarchy to globally manage multiple vendor elements while satisfying local network demands.

BACKGROUND OF THE INVENTION

Telecommunications services have, for many years, attempted to
10 optimize or minimize bandwidth usage between network elements. Since the modern communications era, brought about by the theories of Shannon, telecommunications engineers have been keenly aware of the need to provide optimal, or at least good solutions, to bandwidth allocation problems in point-to-point and point-to-multipoint networks.

15 In wireless communication systems, solutions to bandwidth allocation problems can be seen in the way data is modulated to "share" finite resources. For example, time division multiple access ("TDMA") provides a means for multiple stations to access time slots on satellite carriers and thereby "share" bandwidth resources. Code Division Multiple Access ("CDMA") provides a

means to use code division modulation techniques (time and frequency modulation) for multiple point access to a predetermined range of bandwidth and thereby "share" bandwidth space. Likewise, frequency division multi-access ("FDMA") provides a means to divide up and share a finite bandwidth
5 resource.

More elaborate schemes to dedicate bandwidth in accordance with a predetermined transmission schedule and modulation plan can be seen in U.S. Patent No. 5,592,470 to Rudrapatna *et al.*, ("Rudrapatna") issued January 7, 1997, (the "Rudrapatna patent"). The Rudrapatna patent concerns a terrestrial
10 micro-port network that allocates bandwidth to terrestrial micro-port receivers based on a pre-determined schedule and modulation plan. The pre-determined schedule and plan may be subsequently modified by dynamic demands on the micro-ports. The network can then satisfy the dynamic demands by moving channels between modulation and polarity schemes in pre-determined amounts.

15 In wireless networks, certain communications links require more bandwidth and power resources than others. This is necessary to maintain specified information throughput, to provide appropriate grades of service or due to varying site configurations (*e.g.*, different antenna sizes). Whenever a change in network resource allocations is required to match varying traffic
20 requirements, a new transmission plan may or may not be implemented. This may necessitate programming, transmitting and receiving communications equipment, *e.g.*, amplifiers, modulators and demodulators, to support the new

resource assignments. These and other problems in bandwidth allocation in a multi-vendor network are addressed by the present invention.

SUMMARY OF THE INVENTION

The methods and apparatus disclosed herein may assign and re-assign
5 available transmission resources in point-to-point, multipoint and broadcast wireless networks. This may be accomplished on the basis of information capacity and connectivity requirements between transmitters and receivers of communications links at the time of assignment or re-assignment. The system may also provide a network administrator with novel tools and automated
10 methods to define and implement network transmission plans and to modify allocation decisions as traffic requirements change.

The system may provide the tools to efficiently allocate transmission resources. These tools help implement the communications links that form wireless networks. An optimum resource or a "good fit" allocation is achieved
15 when network users have just enough information transmission capacity to perform their tasks. One way to accomplish optimal or good transmission resource allocations in a wireless network is to analyze network users' usage patterns and allocate capacity according to a time-varying schedule.

By analyzing network usage patterns, a management component can
20 determine a transmission plan schedule that efficiently allocates the satellite bandwidth available to the network based on historical usage patterns. The management component may automatically schedule and implement a transmission plan. As the network users' requirements change, the management

component may update or modify the scheduled transmission plans to satisfy the new requirements.

The system may automate implementation of transmission plans by reprogramming the system when predetermined parameters are reached. For
5 example, the management component may determine a transmission plan from a historical analysis of bandwidth requirements between stations. This transmission plan may be automatically deployed to the network. The management component can then monitor and analyze network allocation demands to determine a new transmission plan. The new transmission plan can
10 then be automatically deployed in the network when predetermined parameters are reached, such as, average change in bandwidth, *e.g.*, bandwidth in use/bandwidth in the transmission plan, exceeds a predetermined amount or if a predetermined amount of time has transpired. The transmission plans may be propagated as generic network commands and translated into corresponding
15 equipment parameters and associated control commands as required for reconfiguring network equipment elements. Thus, the system may generate and distribute equipment configurations to network elements to reprogram for synchronized execution at predetermined times.

The system further controls and schedules bandwidth between network
20 elements to consider other network factors such as economic constraints. In a wireless communications network, each communications carrier should have just enough bandwidth and power necessary to meet the needs of its corresponding users. Although optimum resource allocation is the primary goal,

sub-optimum allocation may be tolerated when economic constraints may limit transmission resources to finite amounts. Thus, for example, a dynamic bandwidth requirement at a network station may require an increase in bandwidth allocation from the station, such as when the queuing depth reaches a predetermined amount at the station switch. The station may have additional capacity available on an available communication link, however, the incremental capacity of the link may far exceed the bandwidth required to reduce the depth of the communication queue. Furthermore, the financial cost of the incremental capacity may exceed the cost of waiting for network usage to decrease to reduce the depth of the queue. The system, in this case, would allow the network to back up and flow control the user data before the system would allocate additional capacity. The system provides methods to use finite transmission resources by enabling power and bandwidth to be re-allocated as needed to meet changing communications requirements in satellite networks. However, the capabilities of the system are applicable to all wireless networks that can be modeled as a collection of transmitters, transmission resources, and receivers.

The system provides a means to manage heterogeneous or multiple vendor network equipment over heterogeneous or multiple vendor transmission resources with multiple transmission paths. One such path may be via programmable C-, Ku-, or Ka- band satellite networks. Other paths may be via discrete carriers available on a preprogrammed networks such as the Inmarsat, Globalstar or Iridium satellite systems. Yet other paths may be via third party

medium or broadband networks such as the envisioned Teledesic satellite network. Yet another path may be over a programmable or managed network such as the Intelsat global satellite system. Thus, the system provides a means to define and manage capacity between network elements where the network
5 may be a combination of a discrete bandwidth allocation network managed by an external system, a semi-programmable medium or broadband network wherein a varying amount of bandwidth may be allocated from an externally managed resource and a fully-programmable network where the resource is managed by a network management component. Thus, the management system
10 provides a nearly transparent means by which an operator, user or network element may place demands on the network and the management system may satisfy those demands based on a least cost algorithm, quality of service parameters and pre-defined or time-varying transmission plans.

The management system described may configure the transmission
15 elements (transmitters and receivers) in a wireless network to implement a specified allocation of transmission resources according to varying, scheduled or ad-hoc capacity requirements. The system maintains a schedule of transmission plan implementations and may automatically perform each implementation at a scheduled time.

20 The semi-autonomous network management system essentially consists of two semi-autonomous components. The first component is the Implementation Component (IC) which executes at a site containing network transmission elements and the second is a Management Component (MC) which

executes at a network management site. These components may be connected via a user datagram Internet protocol messaging format.

At the heart of the system is the IC. The IC may be a stand-alone application program that controls one or more network elements. A network
5 element may be the station or communication equipment physically controlled by an IC. Thus, it is usually the case that the network element is a stationary or mobile communications node at a single physical location. The IC may, however, remotely control a network element.

In one embodiment of the present invention, the IC application may
10 execute in a dedicated processing environment such as a PC executing UNIX or other suitable operating system such as Windows or DOS. The IC may also execute on an integrated or embedded processor such as a PC on a card environment with an application specific or real time operating system. executing thereon.

15 The IC is semi-autonomous, *e.g.*, it can translate allocation commands from a management component into executable commands for its associated network elements without having direct, full-time contact with the network management component. The IC may store pre-programmed parameters, transmission plans, or collection commands for automatic execution. The IC
20 may map a network programming language command set or generic allocation command to a vendor specific command sequence. The IC may contact the management component to receive permission to access network bandwidth, to report the unavailability of network elements, or to request different allocation

parameters if or when local demands exceed the IC's preprogrammed allocations. Thus, the IC may provide independent control over network elements while maintaining or executing a management plan.

In the semi-autonomous network management scheme disclosed,
5 transmission schedules may be loaded in advance of the implementation of the scheduled transmission plans. Then, at a predetermined time, the network can switch over to the new transmission plan to implement the optimal, or at least good solution, before more complicated dynamic bandwidth allocation algorithms would need to be employed.

10 In addition to automatically implementing scheduled transmission plans generated by the management component, the system may also perform network usage analysis. Automated network usage analysis may require that the management component have access to traffic data collected for the network. The data may be collected automatically or manually by the management
15 component or the implementation component may interact with the elements in the network to collect the usage data. The management component may use statistical methods to analyze the gathered network usage data to suggest or implement optimize transmission plans for efficient use of the available resources according to a schedule.

20 Efficient use of bandwidth spectrum may be achieved on various levels in the system. On a first level, bandwidth may be scheduled in accordance with a historical analysis of demands on the network. For example, it may be determined that Monday morning traffic is mostly outbound (*i.e.*, from a central

earth station to a mobile station). On Fridays, however, most of the traffic is in the opposite direction (*i.e.*, from mobile stations back to the central earth station). In this instance, an assymetric channel may be opened for Monday traffic to provide higher outbound data and a slower speed return path. Then the
5 opposite allocation may be established for Friday's traffic (*e.g.*, a high speed channel from a mobile station to the central station and a low speed acknowledgment channel from the central station back to the mobile station). This may provide an optimal, or at least a cost-effective solution for the capacity requirements at a particular time.

10 On a second level, the system may allocate capacity based on class of service parameters available, for example, through an Asynchronous Transfer Mode ("ATM") type packet format. For example, a class of service may identify data packets with low priority for a particular application. In such a case, an expensive satellite carrier may not be necessary and a lower-cost
15 transmission resource may be put online by the network to pass the required data packets. Thus, the present network can mix class of service bandwidth allocation methods with least cost routing decisions based on predetermined parameters programmed in the IC.

The semi-autonomous nature of the network management components
20 may use a datagram protocol for interprocess communication. More specifically, the network components may communicate through the use of the User Datagram Protocol ("UDP") over an internet protocol ("IP").

Communication between the management component and the IC may use a polled or interrupt methodology.

In a polled mode, the management component contacts each of the ICs to pass UDP/IP messages or to receive Transmission Control Protocol/Internet Protocol ("TCP/IP") information from the particular IC. In an interrupt driven mode, the IC may attempt to communicate with the management component. The interrupt mode may be used to re-establish contact with the MC if the IC loses synchronization with the network or to pass alarm or other local conditions happening at the IC that may not be detected by the management component. In the interrupt driven mode, the IC may have a preassigned back-up channel or predetermined bandwidth allocation to communicate with the management component. The management component may be programmed to look for alarm conditions or communication attempts from the ICs when predetermined parameter thresholds are reached.

Additionally, a signaling control mechanism between the management component and the ICs is disclosed. The signaling control mechanism operates to ensure that each of the ICs receives the appropriate message(s) and that the transmission plan may be implemented according to the predetermined schedule.

The signaling control mechanism between management component and implementation components may communicate by exchanging the following UDP/IP messages.

- Transmission Control Order
- Abort Order

- Acknowledgment of a Transmission Control or Abort Order
- Audit Request
- Audit Response

5 A transmission control order ("TCO") specifies new transmission parameters for a transmitter or receiver. The TCO may also specify the implementation time. The implementation time may be the time at which elements should begin using the transmission parameters specified in the order. TCOs are generated by the system to implement a new transmission plan. The

10 system sends TCOs to the ICs of transmitters and receivers that must change parameters to implement the new transmission plan. TCOs may be stored on a hard drive or other non-volatile storage so that they are preserved through IC restarts and at IC power failures.

 It is possible that an IC may be down or may not be able to communicate

15 with the managed equipment at the execution time of a TCO. When this happens, the IC may implement the current transmission plan or may implement a default state when the IC reestablishes communication with the managed equipment.

 The IC may send an acknowledgment of a TCO when a TCO is received

20 from the system. If any of the requested parameter changes cannot be implemented because the managed equipment or the configuration files do not support it, the IC notifies the management component of this in the acknowledgment.

The IC may also check that the parameter values are valid for the managed network equipment. Parameter ranges are specified in the Equipment Controller configuration files in the IC, discussed further below.

5 A confirmation message may not be necessary for reporting the successful implementation of a transmission control order. Because the majority of satellite networks implement single links to each remote site, if an IC is not able to implement a TCO, the IP connection to the system may be lost. The system management component may detect the problem from the lack of audit responses. If the system does not receive an audit response from an IC,
10 the system may update the site status and alerts the management component alarm.

An abort order may instruct the IC to cancel any pending TCO for the specified transmitter or receiver. The system may send abort orders when a pending implementation is canceled by the Administrator. The IC may send an
15 acknowledgment when it receives an abort order. The IC may send an acknowledgment when it receives a TCO or abort order from the management component.

An audit request may be periodically sent to an IC by the management component. The management component may send an audit request to check
20 the status of a transmitter or receiver. One audit request may be sent for each transmitter and receiver being managed by an IC.

An audit response may be sent by an IC when an audit request is received from the management component. The audit response may contain the

current parameter values for the transmitter or receiver specified in the audit request.

An audit response may be similar in structure to a TCO. It may include the hardware identification for a transmitter or receiver and a list of model
5 parameters and their current values as reported by the physical hardware.

The receive frequency model parameter may be a special case: the frequency reported by the demodulator may not match the commanded receive frequency. Sources of frequency error throughout a wireless carrier transmission process may result in an offset between the expected and actual
10 receive frequencies. Many demodulators are designed to accommodate this frequency offset by searching for the transmitted carrier in a neighborhood around the commanded receive frequency. However, the system may also account for this receive frequency offset when determining whether the physical hardware is using the same parameters as in the most recently implemented
15 TCO.

The management component may periodically request the current parameters from all transmitters and receivers. This network auditing function may perform the following functions:

- Maintains the status of communications between the management
20 component and the transmitters and receivers in the network.
- Detects parameter changes of the managed equipment.

When a difference between the specified transmission parameters for a transmitter or receiver and the managed equipment is detected, the management
25 component may notify a Bandwidth Administrator. The management

component operator interface may use an audible as well as visual alert to improve the chance that a Bandwidth Administrator will notice the difference and act to resolve it.

Fig. 21 shows equipment controller IC (150). IC (150) may have a
5 configuration database (152) which stores a configuration mapping for end-user receiver and transmitter equipment which is interfaced by, for example, serial devices (164, 166, 172, 174) and parallel devices (188, 190). The receiver/transmitter equipment may be from multiple vendors and thus the configuration database (152) maps commands from the management component
10 (156) to a particular device. This feature of the IC may allow the use of a generic network control language in commands sent to IC (150) (discussed further below).

The *system* is designed to manage all transmission equipment, regardless of manufacturer. To achieve this, the management component deals with model
15 satellite transmitters and receivers as illustrated in Figure 6.

The transmitter and receiver models have the parameters necessary to implement a wireless link. Only parameters that relate to the establishment of a wireless link need be included in the transmitter and receiver models.

The management component may not require information about the
20 physical equipment elements used to implement the communications links in the managed network. Therefore, the MC need not map the model parameters directly to commands for the physical hardware of the transmitters and receivers

at a site. The IC may have information about the physical hardware at its site and may map the model parameters to the appropriate commands and responses.

The IC may read information about the physical hardware from the configuration files. These files may specify the information required by the IC
5 to monitor and control the managed equipment at a site. The IC configuration files may contain the information necessary to convert parameter changes for the model transmitters and receivers into commands to the physical hardware.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a pictorial schematic of a star topology satellite network
10 showing a shared outbound simplex channel and a private inbound simplex channel.

Fig. 2 is a pictorial schematic of a mesh topology for a satellite network showing shared outbound simplex channels.

Fig. 3 is a functional schematic of a transmission equipment model
15 depicting modulators, up converters, and the loss and gain elements in the circuit, the site antenna, and the corresponding receiving circuits showing gain and loss elements, the down converter, and the demodulator.

Fig. 4 depicts software components for the semi-autonomous network management system of the present invention.

20 Fig. 5 is a functional schematic detailing the software components. At the control site there is a management (control) component, a display controller and an event logger component. At the remote site, there is the IC, the equipment controller component and a display controller and event logger

component. The management transmission and receiver equipment is further shown as being controlled from the IC equipment control.

Fig. 6 is a functional schematic showing the elements of a transmission model that are controlled by the semi-autonomous ICs of the present invention.

5 Fig. 7 shows a further functional schematic of the IC systems.

Fig. 8 is a functional schematic showing the software process architecture of the semi-autonomous network management component.

Fig. 9 is a functional schematic of the information flow in the semi-autonomous components of the present invention.

10 Fig. 10 is a graphical depiction of the transmission plan allocation of available spectrum.

Fig. 11 is a graphical depiction of the transmission plans of a transmission plan schedule.

15 Fig. 12 is a graphical depiction of a transmission plan schedule implemented throughout a particular day.

Fig. 13 is a flowchart illustrating a method of transmission plan deployment and execution.

Fig. 14 is a flowchart illustrating a method of executing a bandwidth allocation request.

20 Fig. 15 is a graphical depiction of a UDP datagram format employed in the management components.

Fig. 16 is a functional schematic of the request/command flow direction of the present invention.

Fig. 17 is a flowchart illustrating a method of grading, employing, and implementing transmission plans within the network.

Fig. 18 is a graphical depiction of how the methodology of the present invention views transmission media as resources.

5 Fig. 19 is a graphical representation of the methodology of the present invention allocating transmission media resources.

Fig. 20 is a graphical depiction of a timing transmission plan implementation.

10 Fig. 21 is a graphical depiction of the command processing flow in the equipment controller.

Fig. 22 is a graphical depiction of the process flow for network audit processing.

Fig. 23 is a graphical depiction of the auto command flow with respect to timing.

15 **DETAILED DESCRIPTION OF PREFERRED EMBODIMENT**

The system is composed of two software components, the Management Component ("MC") and the Implementation Component ("IC") that work together to monitor and control the transmission elements in a wireless network.

20 The MC includes an operator interface for configuring, monitoring, and controlling the capacity allocation activity in a wireless network. It may be a Win32 application that runs on a Windows NT workstation which may be located at a network operations center (NOC). Configuration, monitoring, and control of the capacity allocation may be accomplished with the management

component. The MC communicates with the other software component, the IC, using the Internet Protocol (IP) family of network protocols as illustrated in Figures 4 and 5.

5 The IC is the application that may communicate with the physical hardware elements implementing the communications links in a wireless network. The IC may be a Win32 application that runs on a computer located at each site in the network. The IC may read a set of configuration files that describe the network equipment to be monitored and controlled. These configuration files may be text files and may be created and modified with a text
10 editor program. In general, the configuration files are re-usable, that is the same configuration file may be used at multiple sites if the same network equipment is used at both sites.

As discussed above, the MCs and ICs communicate by exchanging IP messages. Figure 5 is a representation of the connectivity between the
15 management component and the IC in a wireless network. The IP connections may be implemented on the satellite network, through the Internet, or through a private network. A second physical communication path between the MC and the ICs may be used to establish IP communications. Typically, ICs do not communicate with other ICs; however, communication links may be established
20 between components to further communication with the MC.

The management system is designed around several elements. These are the

- Transmission resource
- Site
- 5 • Transmitter
- Receiver
- Transmission element
- Transmission plan
- Implementation
- 10 • Schedule
- Execution time

A *transmission resource* may be a portion of a wireless capacity (power and bandwidth) that may be used by the transmitters in a network. A *site* may be a
15 collection of transmitters and receivers controlled by a single IC. Normally one IC controls all of the transmitters and receivers at a network site. However, the transmitters and receivers at a network site may be controlled by more than one IC. For example, this may occur at a hub site in a satellite network with a star configuration.

20 A *transmitter* is an equipment element that modulates an information signal so that it may access a wireless media. A *receiver* is an equipment element that demodulates a signal received from a wireless media to recover the information from the broadcast signal. A *transmission element* may be a transmitter or receiver in the network configuration. Although transmitters and
25 receivers may be different and perform different functions, the management component may perform some operations in which transmitters and receivers are both treated the same way. For example, the MC may audit the status of all transmitters and receivers in the network. The management component may not

distinguish between transmitters and receivers when performing this auditing operation.

A wireless link may be created when an information signal is modulated by a transmitter and then demodulated by one or more receivers. A wireless
5 communication network is a collection of communications links that enable information transfer among the sites in the network. Each link requires some of the transmission resources available to the wireless network. The allocation of the available transmission resources among the transmitters in a network is a *transmission plan*. These transmission plans may define the information
10 capacity and connectivity requirements between the transmitters and receivers in the network.

Only transmitters may need to be specified in a transmission plan. Transmitters generate the signals that use transmission resources. The number of receivers demodulating a wireless signal does not affect the amount of
15 transmission resources (bandwidth and power) used to implement the link.

Implementation may be the process of configuring the transmitters and receivers in a wireless network to allocate the transmission resources as specified in a transmission plan. The management component may implement a transmission plan by sending orders to the ICs controlling the transmitters in the
20 transmission plan and the receivers listening to those transmitters. These orders may specify the transmission parameters for the transmitters and receivers and when they should be implemented. The IC may send the equipment-specific commands that implement the transmission parameters at the specified time.

The *implementation schedule* may be a list of all transmission plan implementations that may automatically be executed in the future. The schedule may be maintained by the MC application. An operator may add implementations to the schedule, remove implementations from the schedule, and move existing implementations to different times. An *execution time* consists of a transmission plan and the time at which the transmission will be implemented. The time may be a recurring time, for example 1200 UTC every day or 0600 UTC every Monday. The implementation schedule may be built from execution times.

10 The information architecture of the system applies primarily to the structure of the database maintained by the Management Component and may define the structure of the messages exchanged between the management component and ICs.

15 The information maintained by the management component (network configurations, transmission resource configurations, transmission plans, etc.) may be stored in a relational database.

20 The management component may require information about the wireless networks that it manages. A network may be viewed as being composed of sites, transmitters, and receivers. Information about these objects, *e.g.*, sites, transmitters and receivers, and the relationships among them may constitute a *network configuration*. A *network* may be a collection of sites that are linked by transmission resources. The following information may be specified for each network managed by the system:

- ☐ Name
- ☐ Transmission resources available for use by the network

The system may maintain the following information for each network:

- 5 ☐ Network ID
- ☐ Status
- ☐ Sites in the network

A *site* may be the physical location of an antenna in a wireless network.

- 10 In addition to an antenna, a site may have at least one transmitter or receiver.

The system may require that the following information be provided for each site:

- ☐ Name
- ☐ NMS IP address
- 15 ☐ Location (street address, geographic coordinates, etc.)
- ☐ Contact information (telephone numbers, operators' names, radio frequencies, etc.)
- ☐ Antenna parameters (size, gain, etc.)

- 20 The system may maintain the following information for each site:

- ☐ Site ID
- ☐ Status
- ☐ Network to which the site belongs
 - ☐ Transmitters at the site
- 25 ☐ Receivers at the site
- ☐ Time of last management component transmission to site
- ☐ Time of last IC response from site

- In the system, a *transmitter* may comprise the equipment necessary to convert a
- 30 digital data stream into a carrier for transmission over a wireless resource. The system may require that each transmitter be uniquely named. The system may maintain the following information for each transmitter:

- ☐ Transmitter ID
- ☐ Status (UP, DOWN, FIXED, UNKNOWN)
- ☐ Site where the transmitter is located
- 5 ☐ Receivers that should be receiving the transmitter's carrier(s)

The system may track the status of the transmitters in a wireless network. Possible status values for the tracked components may be:

- | | | |
|----|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10 | UP | the transmitter is currently generating a carrier and is under the control of the management component |
| | DOWN | the transmitter is not generating a carrier but is under the control of the management component |
| 15 | FIXED | the transmitter is generating a carrier and the management component knows the characteristics of the carrier but the transmitter is not under management component control |
| 20 | UNKNOWN | the management component does not know if the transmitter is generating a carrier |

In the system, a *receiver* may comprise the equipment necessary to receive a carrier transmitted over a wireless resource and recover the digital data stream. The following information may be specified for each receiver:

- 25 ☐ Name
- ☐ Transmitter of the carrier the receiver should receive

The system may maintain the following information for each receiver:

- 30 ☐ Receiver ID
- ☐ Status
- ☐ Site where the receiver is located

A *pool* may be a collection of transmission resources available for use by the managed networks. Each transmission resource is a portion of transmission

capacity (power and bandwidth). The following information may be required for each pool:

- ☐ Name
- ☐ Transmission resources in the pool

5

The system may maintain the following information about each pool:

- ☐ Pool ID
- ☐ Networks using the pool

10

A *transmission* resource may be a portion of transmission capacity (power and bandwidth). The system may require the following information about each transmission resource:

- ☐ Description (transponder, provider, etc.)
- ☐ Start frequency
- ☐ End frequency
- ☐ Translation offset
- ☐ Power allocation
- ☐ Cost metrics

15

The system may maintain the following information about each transmission resource:

- ☐ Transmission resource ID
- ☐ Pool to which the Transmission resource belongs

20

A *transmission plan* is an allocation of transmission resources to one or more carriers in a wireless network. The system may specify the following information about a transmission plan:

- ☐ Execution time
- ☐ Duration
- ☐ Comments

30

The system may maintain the following information about a transmission plan:

- TP ID
- State (UNSCHEDULED, SCHEDULED, PENDING, READY, STARTING, ACTIVE, COMPLETED, or CANCELLED)
- BARs satisfied by the TP

The system may manage sites with multiple transmitters and receivers. Therefore the system maintains a naming scheme for identifying a specific transmitter or receiver at a site.

Figure 9 may represents the flow of hardware identification information from the IC configuration files to the management component. The identification information may originate in the configuration files generated for a site in a network. The configuration files for a site may be read by the IC.

Figure 9 shows the information flow in the system. Each transmitter and receiver at a site may be designated by an equipment class. Each member of a class is assigned an instance number. Together, the equipment class and instance identify a unique transmitter or receiver at a site. A Bandwidth Administrator (902) may supply the hardware identification when configuring the transmitters and receivers of a site for bandwidth management. The flow of information shown in figure 9 simplifies network configuration maintenance and reduces the risk of problems due to inconsistent configuration information in the network. The circles with a slash (914, 916) illustrate that neither the Bandwidth Administrator (902) nor the management component (906) require access to the configuration files (910).

The system software components may exchange information by sending and receiving messages using network or external connections. The management process may communicate with all of the IC processes. Each IC communicates only with the management component.

5 The User Datagram Protocol (UDP) of the Internet Protocol (IP) suite may be used to transport the inter-process messages. The system may use the combination of IP address and UDP port to identify the ICs in the network. Site identification information may not be required in the message if the IP address and port are already available in the IP and UDP headers.

10 The management and ICs may communicate using several types of messages. Although each type of message contains different information and fulfills a different purpose, the message types share some common characteristics as shown in Figure 15.

- 15 ☐ A message is sent as a single UDP datagram
- ☐ Only ASCII characters are allowed in a message
- ☐ A message is a series of information fields
- ☐ Fields are terminated with an ASCII linefeed (LF)
- ☐ A message is terminated with an empty field (single LF)
- 20 ☐ The first three fields are the same for any message (message type, sequence number, and hardware identification)

Although system messages contain only ASCII characters, the messages may be compressed before delivery via UDP. Messages may then be uncompressed after receipt. Fields #4 through #N (1514, 1518) in figure 15 are *information*
25 *fields* (1524). The fields prior to the information fields in a BMF message are *header fields* (1528).

Header fields may be present in system messages (1528). Typically, the order and format of the header fields are the same, regardless of message type. The format of a header field is simple: a string terminated by an ASCII linefeed (LF) character (1504, 1508 and 1510). The string can contain any printable

5 ASCII character except LF. The management and ICs may communicate using the following message types:

- ☐ Transmission Control Order (TCO)
- ☐ Abort Order (ABRT)
- ☐ Acknowledgment (ACK)
- 10 ☐ Audit Request (AREQ)
- ☐ Audit Response (ARSP)

The mnemonic in parentheses after each message type is the identifier used in the first field (1502) of a system message (1526). After the message type
15 field, the next field in a system message is a sequence number (1506). The management component maintains a sequence number for each piece of managed equipment (*e.g.*, receiver or transmitter) in a network. The IC may use the sequence number from a request message in the response message.

Sequence numbers may be used to match responses (ACK or ARSP)
20 with requests (TCO, ABRT, or AREQ). The use of sequence numbers (1506) prevents confusion when multiple responses are received when multiple requests were sent due to message delivery delay or temporarily unavailable components.

Figure 18 illustrates a transmission plan for allocating transmission
25 media resources among transmitters in a network. Figure 18 shows that a transmission media can be divided up into discrete segments (10). A network

management plan can view discrete segments (10) of bandwidth as discrete transmission media sources (12). A transmission plan (16) may be used to map a network transmitter (18) through a link (14) to a predefined transmission media resource (12). For example, transmission network transmitter (20), in
5 particular transmitter (18), may be mapped through transmission plan (16) to two discrete segments (10) through link (14). The network media resource may be a star topology as shown in Fig. 1 or a mesh topology as shown in Fig. 2.

Network transmission media resources may also be on separate networks. For example, a first network transmission resource may be capacity
10 from the INMARSAT satellite network or through private networks on a C, KU, KA or L-Band. The network transmission resources may be further augmented by low earth orbiting satellites, medium earth orbiting satellites or geosynchronous satellites. Low earth orbiting satellites may be represented by the Iridium system employed by Iridium, Inc., whose discrete bandwidth
15 allocation methodology is herein incorporated by reference. Geosynchronous satellites may also provide additional transmission resources as represented by the Inmarsat or Intelsat satellite services whose bandwidth allocation methodologies are herein incorporated by reference.

The management component or the ICs do not need to be in direct
20 control of the bandwidth allocation to utilize transmission media sources. For example, bandwidth allocation on the Iridium satellite system may operated independently of the management component and the ICs. However, the bandwidth allocation methodologies of, for example, the Iridium network, may

be employed to treat the resultant communication path as a transmission media resource under control of the management component. Indeed, multiple carriers from a third-party system may be allocated in discrete predefined units, such as discrete segments (10), shown in Fig. 18, for utilization by the present invention
5 as a media resource.

Fig. 19 is a graphical depiction of network elements, ICs, a management component and a transmission plan. A central controller of the present invention may be represented by Management Component ("MC") (30). MC (30) is in communication with a plurality of ICs ("ICs") (32, 34, 38, 40) through
10 links (31). Each IC may represent a particular site that is under network management control by the MC. Each IC may have network equipment (42) under its control. For example, IC (40) has transmitter (44) under its control and BIC (38) has receivers (46, 48, 50, 51) and transmitters (56, 57) under its control. IC (36), however, has receiver (54) and transmitter (52) under its
15 control. The present invention implements a transmission plan (43) through a mapping of network equipment (42) to transmission media resources (46). For example, transmitter (44) has been allocated transmission media resource (45) for reception by receiver (48) as indicated through up link and down link mappings in transmission plan (43). This may represent a combined
20 transmission media resource whose overall capacity is the entire discrete amount allocated at transmission media resource (45). For example, a dynamic bandwidth requirement for a connection at a predefined class of service may be split into two discrete carriers. The discrete carriers may be represented by the

two discrete media resources allocated at transmission media resource (45) to provide an overall throughput necessary to accommodate the predetermined capacity to support the class of service. The excess capacity may be used to provide the time recovered to reassemble the packets at receiver (48). This methodology is useful in the instance where, for example, a class of service from a particular end-user exceeds the network capacity to satisfy the demand on a single channel or contiguous media resource. For example, the class of service requires a connection that exceeds the bit rate capacity of the modulator at a particular transmitter, but two modulators would supply ample bandwidth for the class of service. In that instance, the IC or the management component could divide a packet data stream from the end-user device onto the two different modulators. In that instance, multiple transmission media resources may be allocated to satisfy the overall class of service demand.

A further representative example of a transmission plan employed herein is a broadcast from IC (38) through transmitter (56) which has been allocated transmission media resource (57). Transmission media resource (57) may be used for reception by both IC (34) and receiver (58) and IC (32) and receiver (60). This is an example of a point to multi-point broadcast. The point is represented by uplink transmitter (56) and the multi-points are represented by receivers (58) and (60). One representative application of such a plan is, for example, a broadcast message from transmitter (56) to two simultaneous sites represented by ICs (32) and (34).

Another representative example of a transmission plan employed herein is transmitter (57), under control of IC (38), having an allocation of transmission media resource (61) for reception by receiver (54). IC (36) has transmitter (52) and transmission media resource (53) allocated for reception by receiver (50) at IC (38). This transmission plan may represent an asymmetric transmission, *i.e.*, the outbound channel from IC (38), represented at transmitter (57), has more media resources allocated which may indicate a higher bandwidth or higher data rate for reception by IC (36) through receiver (54) than the outbound channel from IC (36) through transmitter (52) through transmission media resource (53) for reception by receiver (50) to IC (38). Other representative permutations of the transmission plans employed herein are shown in Fig. 19 through the mapping transmission plan (43).

Fig. 20 demonstrates the timing of how a representative transmission plan may be implemented by the management component. The transmission plan implementation begins with management component (100) having a predetermined command (102) to send to the network at a predetermined command time (110). Command(s) (102) is sent to IC (104) that must change transmission resource allocation at the implementation time. This command is stored in IC (104) and the time to implement the command is decoded by IC (104). IC (104) then sends a command acknowledgment (118) back to a management component (100). At this juncture, command (102) is loaded and awaits deployment at MC (100) at the predetermined command time (110).

Command (102) is resent (122) if acknowledgment of receipt of command (118) is not received before a predetermined time.

It is understood that MC (100) may have a list of every IC (104) in the network that must change. This list may include the TCP/IP address for each IC (104) so MC (110) may send a UDP/IP message with a command (102) encoded therein. An acknowledgment deadline (134) is included that may be seconds before the implementation time for the new transmission plan. The acknowledgment deadline (134) may be the last time at which MC (106) can abort an implementation if each IC (104) does not acknowledge the commands.

It is understood that IC (104) may use a coordinated implementation to assure that no IC (104) is stranded when the transmission plan is implemented. During the abort sequence, which occurs if IC (104) has not acknowledged command (102) at step (118), MC (106) sends an abort message (126) to IC (108) that were sent command (102). IC (108) may send an abort acknowledgment (128). Abort command (126) is resent at step (130) if it is not acknowledged. The implementation time (136) defines a time at which the transmission plan is executed by IC (104). It is understood that at that point, all necessary ICs (104) have acknowledged command (118) and are counting down in a synchronized fashion to the predetermined implementation time (136). It is understood that the command acknowledged may include an indication of the time at which an IC (104) received command (102) to verify that the implementation time (136) is synchronized among each IC (104). Once all commands have been acknowledged and the network is ready to implement the

plan, at implementation time (136), the ICs (104) implement the command(s) received from MC (100) at implementation time (136).

At this point, a new transmission plan, as depicted in Fig. 19, may be implemented by the network. The communication path between MC (30) and
5 ICs (32, 34, 36, 38, 40) is independent of the transmission media resources. As depicted in Fig. 19, a transmission path (31) is generally over a TCP/IP network (e.g., the Internet), as widely known in use today. However, it is within the scope of the present invention to define a guard or maintenance channel which may be a point-to-multi-point transmission scheme from MC (30) to and from
10 ICs (32, 34, 36, 38, 40) wherein an IC co-located with MC (30) assures that a network connection is present between ICs (32, 34, 36, 38, 40) and a MC allocated transmitter, such as transmitter (44). In such a case, each IC (32, 34, 36, 38, 40) ready to implement the new transmission plan may have a receiver dedicated to monitor transmitter (44) to receive abort command (126) if each IC
15 (32, 34, 36, 38, 40) does not acknowledge. This assures a fail safe or guard channel back-up plan to abort implementation of a new transmission plan if one or more IC (32, 34, 36, 38, 40) loses communication with the management component.

Commands may enter the IC (150) from a plurality of sources, one of
20 which may be directly from the MC. Node (158) may be a UNIX daemon or a Windows NT™ service which monitors a TCP/IP address. Thus, commands from MC (156) may enter IC (150) through a port (204). Upon entering IC (150), network commands may be mapped at step (158) in conjunction with

configuration database information to output specific commands (178) to the network equipment. These commands may be put into a command queues (168, 180, 184) which is then directed through a scheduler process 162, 170 and 186. For example, scheduled command implementation processes (162, 170, 186) may output commands to the appropriate receiver, transmitter or network device through a serial port (164, 166, 172, 174) or a parallel port (188, 190). Command queues (168, 180, 184) may be a polled or interrupt driven queue. That is, the schedule command implementation process (164) may periodically poll queues (168, 180, 184) to determine whether a command is present, and if so, pass the command on to the appropriate network device interfaced (e.g., serial device driver (164, 166)) or the command key may be a period.

The command queue may alternatively be interrupt driven. That is, when a command enters queue (168, 180, 184), for example, command queue (168) may send an interrupt to the command implementation process for the command implementation process to service the command and then pass it to the appropriate network device at the appropriate serial port. It is understood that this process may be used for implementation processes (170, 186) as well.

Command implementation processes (168, 170, 186) may be synchronized to network time (202) to execute commands at the appropriate time. That is, implementation of transmission plans may be synchronized with network time (202) to assure that all network devices reconfigure themselves simultaneously or near simultaneously. Implementation processes (168, 170, 186) may also have data from configuration database (152) to configure

implementation process (168, 170, 186) for the particular end-user network device. This provides flexibility in implementation process (168, 170, 186). That is, the implementation may be written as a modular software program which may be modified by configuration database data (160) as implementation
5 process (168, 170, 186) executes. Further to this concept is that MC (156) may address configuration database (152) via link (204) to change configuration database (152) to redefine the end-user equipment. This allows the MC (156) to manage the end-user equipment remotely from the user location at the IC site. IC (150) may communicate through module (158) via link (182) to send
10 acknowledgments (200) back to the MC (156). Command acknowledgments (118) shown in Fig. 20 and order acknowledgments may also be used. Figs. 21-28 illustrate a step that may be used to confirm receipt of commands or to confirm receipt of an abort command.

It is understood that there are at least two ways in which to map MC
15 commands or at least two ways in which to map MC commands to the end-user device or to a particular port on a IC. First, a TCP/IP address is provided for the IC in command (204) and then, within the UDP command, is a sub-address that may be decoded at (158) addressed to a particular end-user device.

Fig. 22 shows a graphical block diagram of an audit control process by
20 which the present invention may collect data from network equipment. Equipment controller (150) may have a configuration database (152) which controls the configurations of the IC in relation to the end-user network equipment. An audit request (252) may be received from the MC via port (254).

Port (254) may be a user data packet via a TCP/IP network to a particular predetermined address at (256). At (256), an auto request command may be decoded to map an equipment name to hardware identification from those stored in configuration database (152). The process at (256) may also be used to map
5 equipment attributes to data controls (290). These parameters may be passed to the reformat command process at (280) which is used to provide a formatted audit response (282) to the MC.

In one embodiment of the present invention, the MC may establish an asynchronous data collection process (262, 264, 266) for the network equipment
10 at a respective data port (268, 270, 272, 274, 276, 278) for the network equipment. Asynchronous data collection process (262, 264 266) may be interrupt or poll driven.

In the interrupt driven embodiment of asynchronous data collection process (262, 264, 266), the end-user device may send out an unsolicited
15 command via the respective device (e.g., device 268), to asynchronous data collection process (262, 264, 266). The interrupt then invokes the program to service the data condition (or possibly an alarm) from the network equipment. Asynchronous data collection process (262, 264, 266) then moves the data to the data control store block (258) where the alarm or data condition may be stored
20 in the IC. It is understood that the data control store block (258) may be a hard drive or other long term storage means available at the BIC. In a preferred embodiment, the data control store is a non-volatile data storage media and the asynchronous data collection process is a modular program because it is

modified from data from configuration database (260) for the particular network device. This provides a flexible programming methodology for the asynchronous data collection process employed in the present invention.

In the polled embodiment of asynchronous data collection process (262, 5 264, 266), asynchronous data collection process (262), for example, may periodically poll the end-user network device attached to, for example, port (268), to receive data or alarm conditions from the end-user device. The polling rate may be a parameter from the configuration database received via link (260).

In sum, an audit request may be received via port (254) and decoded at 10 (256) to output data from the data control store program (292). Data output from the data control store may be formatted at (280) from parameters past (290) from the audit request. This can provide an auto response (294) back to the BMC (282) in the appropriate and predetermined format.

Fig. 23 shows a logic flow representation of a network audit from a MC 15 (302). In Fig. 23, the MC (302) may establish an auto time for a network element, a transmitter or receiver (300). At the appropriate time, MC (302) may send out an audit request (306). It is understood that audit request (306) is directed to the network element and the particular IC controlling that element (308). The IC may then query the network element and send an audit reply 20 (312) to the MC (310). Audit reply (312) is shown in time synchronization (316) after audit request (306).

Initialization or configuration files may be used to implement the invention. Exemplary initialization files are shown in Appendices A-H. For

example, a "command.ini" file (shown in Appendix A) may be used to provide user interface command definitions for all network management system equipment supported. The "command.ini" file specifies the menus associated with each control used on a user display.

- 5 A "monitor.ini" file (shown in Appendix B) may be used to specify automatic monitoring functions performed by an equipment controller. The "monitor.ini" file may act as the network management system data connection interface definition file.

- 10 An "equipctl.ini" file is shown in Appendix C. The "equipctl.ini" file may be used as the network management system controller initialization file. That is, the "equipctl.ini" file specifies some global parameters for the equipment controller application. It may also specify the location of other configuration files if such files are not stored in a default or pre-determined location.

- 15 Appendix D shows an exemplary "event.ini" file. The "event.ini" file may provide descriptions of network management system events. For example, the "event.ini" file may specify textual responses (to user commands) displayed on a user interface and the asynchronous messages sent to either an event logger or other device.

- 20 A "port.ini" file (shown in Appendix E) may be used as the network management system external connection definition file. The "port.ini" file may specify particular serial and parallel ports used by the equipment controller application.

Appendix F shows an example of a "serial.ini" file. The "serial.ini" file may be used as the network management system serial command description file. This file may specify the command and response strings used to communicate with the manage equipment over a serial interface.

5 An example of a network management system user interface definition file ("panel.ini" file) is shown in Appendix G. The "panel.ini" file may be an the overall specification for the display controller presentation. This file ties together the display controls with specific input/output ports and describes the total graphic user interface for an equipment controller site.

10 Appendix H shows an exemplary "template.ini" file. The "template.ini" file may be used as the network management system display template description file. This file specifies the graphic qualities of the controls used in the display controller presentation. Graphic qualities may include the position of the graphic control on a display, the type of display object, the name of any
15 required bitmap graphic file, and a reference to any menu associated with the control.

The hardware identification field (1510) may contain information that identifies a specific transmitter or receiver at a site. The hardware identification field may have the format:

20 HWID=<Class>:<Name>

where

<Class> is the type of hardware and

<Name> is the name assigned to a specific piece of hardware in the IC configuration.

The type of hardware may be one of the following classes:

- 5 ☐ Transmitter (TX)
- ☐ Receiver (RX)
- ☐ Upconverter (UC)
- ☐ Downconverter (DC)

The <Class> portion of the hardware identification field may be one of the
10 mnemonics shown in parentheses. Information fields (1524) and header fields (1528) may share some similarities. Each type of field is terminated with an ASCII linefeed (LF) character (1512, 1522). The primary difference between header fields (1528) and information fields (1524) is that the same header fields are found in all system messages while different messages can have different
15 information fields.

Because of the size of information fields (1524), the format of an information field is more complex than the format of a header field. Information fields may match the format:

<mnemonic>=<value>

20 where

<mnemonic> is a mnemonic representing the field type and

<value> is a string representation of the field value.

Both the mnemonic and the value of an information field may consist of printable ASCII characters. However, the ASCII character '=' is used to

separate the mnemonic and value portions of an information field. Therefore, '=' cannot be present in either the mnemonic or value strings.

A *transmission control order* (TCO) is sent from management component to an IC to request parameter changes for a transmitter or receiver controlled by the IC.

A TCO may have the following information fields:

- ☐ Execution time
- ☐ Model parameters

The execution time field specifies the time at which the TCO must be implemented. The TCO for each side of a communication link (transmitter and receiver) may have the same execution time to minimize the time the carrier is down during the change. Execution times may be given in UTC. The execution time field may have the format:

ET=<YYYY><MM><DD><hh><mm>

where

<YYYY> is the four-digit year number (0000 to 9999),

<MM> is the two-digit month number (January is "01", etc.),

<DD> is the two-digit day of the month (01 to 31),

<hh> is the two-digit hour of the day (00 to 23), and

<mm> is the two-digit minute of the hour (00 to 59).

All of the fields in a TCO after the execution time are model parameters. These fields are the parameter values for the transmitter or receiver specified by

the hardware identification field of a TCO. Model parameters are specified as a parameter/value pair. The format of a model parameter in a BMF message is:

<mnemonic>=<value>

where

- 5 <mnemonic> is the mnemonic for a model parameter and
 <value> is a string representation of the parameter value.

 An *abort order* (ABRT) may be sent to an IC to cancel any pending TCO for the specified hardware. An ABRT does not require any information
10 fields.

 An *acknowledgment* (ACK) informs the management component that the IC received the TCO or ABRT. An ACK is the response message for a TCO or ABRT. When an IC receives a TCO or ABRT, it must send an acknowledgment to the management component. If the IC detects any problems
15 with the TCO (configured hardware does not support a model parameter, hardware ID invalid, etc.) then the ACK will describe the problems. An ACK for an ABRT does not require this problem description. An ACK may have the following information fields:

- 20 ☐ Execution time (same as in TCO)
 ☐ Model parameters (only if an error condition exists)

 An ACK may have the same information fields as the TCO that is being acknowledged. However, model parameter fields are only present if the IC cannot fulfill that model parameter. For example, if the TCO contained an

invalid receiver bit rate but a valid receiver frequency then the ACK would include an information field for the RXR model parameter but not for the RXF model parameter.

5 An *audit request* (AREQ) is sent periodically by the MC for each transmitter and receiver in a satellite network. Each AREQ is sent to the BMF IC responsible for managing the specified transmitter or receiver. An AREQ does not require any information fields.

An *audit response* (ARSP) is sent by an IC in response to an AREQ from the MC. An ARSP is the response message for an AREQ. An ARSP has
10 the following information fields:

- ☐ Execution time (time ARSP generated)
- ☐ Model parameters (actual settings)

The format of an ARSP may be almost identical to the format of a TCO:
15 the message contains an information field for all of the model parameters pertaining to the specified piece of hardware. However, the values of the model parameters may be the actual settings of the hardware, not the desired settings.

One purpose of the ARSP is to determine the state of the hardware in the network. A secondary purpose is to check for manually instituted changes to the
20 configuration of the network hardware. For example, an operator at a remote site might manually change the receiver frequency using the front panel of the equipment. The management component periodically requests the current state of all managed equipment to check for parameter modifications not initiated by

the management. The execution time for an audit response is the time at which the ARSP is generated.

An ARSP may contain the model parameters for the type of equipment specified by the hardware identification. When the value for a model parameter is not available, the value portion of the field may be "UNKNOWN." For example, if the scrambling state of a transmitter cannot be determined by an IC, the field "SCR=UNKNOWN" may appear in the audit response.

The IC (IC) may read its configuration files at startup and construct memory resident database tables and data 'objects' to facilitate rapid access to the configuration information stored in those files. Among the data read from the configuration files are the records that describe the equipment that the Management Console (MC) application will attempt to control by its commands to the Equipment Controller. The MC may communicate with the Equipment Controller in message with a format similar to:

Equip=EquipmentClass:EquipmentUnitName

Attribute1=Value1

Attribute2=Value2

where 'EquipmentClass' and 'EquipmentName' are character string values that occur in the IC configuration files as identifying a piece of modeled equipment. The values of 'Attribute' and 'Value' are also represented as character strings and hence the entire dialog between the MC and IC is through text based messages.

The IC configuration files identify one or more pieces of modeled equipment and a set of attributes that the modeled equipment can support. For example, the following section of an 'equipctl.ini' file describes an equipment element known as 'TRANSMITTER:Outbound'. The modeled attributes are identified by the 'EquipModemAttrs' entry and list the values TXF TXR MODT MODR ENCT ENCR DENC SCR PWR CXR as the legitimate attributes of the unit known as 'TRANSMITTER:Outbound'.

[Outbound]

10 EquipName=Outbound

EquipClass=TRANSMITTER

EquipModelAttrs=ALL TXF TXR MODT MODR ENCT ENCR DENC SCR
PWR CXR

EquipAttrSetCmds="" EFDDataTxfSetCmd EFDDataTxrSetCmd

15 EFDDataModtSetCmd

EFDDataModrSetCmd EFDDataEnctSetCmd EFDDataTxrSetCmd

EFDDataDencSetCmd EFDDataScrSetCmd EFDDataPwrSetCmd

EFDDataCarrierSetCmd

EquipAttrSetCmdParms="TXF TXR ENCT PWR" "TXF" "ENCR TXR"

20 "MODT" "MODR" "ENCT" "ENCR TXR" "DENC" "SCR" "PWR"
"CXR"

EquipAttrSetCmdPorts=Serial5

EquipAttrSetCmdAddrs="1"

EquipAttrMonConns="" EFDataTxfMon EFDataTxrMon EFDataModtMon
 EFDataModrMon EFDataEnctMon EFDataEncrMon EFDataDencMon
 EFDataScrMon EFDataPwrMon EFDataCarrierMon
 EquipAttrMonConnPorts=Serial5
 5 EquipAttrMonConnAddrs="1"
 AssociatedEquipment=RECEIVER:Demod1

This configuration entry may also associate other configuration entries with the equipment attributes that permit the equipment controller to set
 10 (modify) and get (recover) the attribute values from an actual piece of serially attached equipment. The entries in the list of 'EquipAttrSetCmds' refer to entries in the 'serial.ini' file that describe the actual command to be sent. The entries in the 'EquipAttrSetCmdPorts' and 'EquipAttrSetCmdAddrs' describe which serial port the attached equipment is connected to and the address of the
 15 attached equipment (in the case that multiple pieces of equipment are attached via the same serial port). Similarly, the 'EquipAttrMonConns' entry refer to configuration entries in the 'monitor.ini' file that describe the mechanism by which the attribute is recovered from the attached equipment and the 'EquipAttrMonConnPorts' and 'EquipAttrMonConnAddrs' describe the serial
 20 ports and addresses used for data recovery.

Hence the IC is in not actually aware of the semantics of the data values it is 'setting' or 'getting' and the mapping between the equipment and equipment

attributes that the MC believes it is controlling is completely defined by the equipment controller configuration files and not equipment controller software.

The MC and IC communicate via the text format generally described above. All communication is initiated by the MC. Three request packets are currently defined: 1) a request to modify the attributes of a particular piece of equipment at a particular time in the future, 2) a request to cancel the request to modify the attributes of a particular piece of equipment, and 3) a request to return the current values of the attributes of a particular piece of equipment. Each request is normally responded to with a complementary message. In some cases, however, no response message purposely generated in order to communicate a negative response.

The request to modify the attributes of a particular piece of equipment is known as a Transmission Change Order (TCO). The format of a TCO is as follows:

15

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

Time=YYYYMMDDHHMM

Attribute1=Value1

20 Attribute2=Value2

When the IC receives a TCO it validates the request. The request validation includes confirming that the requested change time has not already past and that

the IC configuration supports the requested modifications. The IC may refer to its memory resident database of configuration data to validate request. First, the IC may insure that the requested equipment is identified in the configuration. It then may insure, by tracing the attributes named in the request through the configuration to the commands that must be issued to insure that sufficient configuration information is present to form the required commands. Finally it may check to see if the equipment is currently responding to commands.

If an error is detected such that the request cannot be supported by the configuration, a response may be returned to the MC identifying the offending request data. For example, if a request contained an equipment identification that did not exactly match an entry in the 'equipctl.ini' file or if an attribute name did not exactly match one of the legitimate attributes named in the 'equipctl.ini' file, a response would be sent indicating why the TCO was invalid and implicitly indicating that the request would not be implemented. Further, if a legitimate attribute is named, but the equipment controller finds that either no serial command is referenced or that the referenced serial command is not configured, the IC may also send a similar response indicating why the request cannot be implemented. Validation of the parameter values may also be accomplished in a similar technique.

If the request is otherwise correct, but the equipment is currently not responding to serial commands, no response is purposely generated, which may indicate that no problem was detected in the request but that the since no acknowledgment was sent, the request will not be implemented at the specified

time. Otherwise, an acknowledgment is returned to the MC indicating that unless otherwise instructed, the IC will perform the requested configuration change at the requested time. The request to cancel the modification of the attributes of a particular piece of equipment is known as a Abort Message
5 (ABRT). The format of an ABRT is as follows:

ABRT

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

10

The IC may remove the outstanding command set to be issued to the specified equipment if any command is queued and may send an acknowledgment to the MC indicating it has done so. If, at the time of receipt, no command is outstanding, the IC may respond with a message indicating that
15 no command was found. The request to recover the current values of the attributes of a particular piece of equipment is known as an Audit Message (AUDIT). The format of an AUDIT is as follows:

AUDIT

20

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

AttributeName (optional)

AttributeName (optional)

The MC may request the current values of the equipment attributes by sending an AUDIT message to the IC. The message may contain specific attribute names or, in the absence of any attribute names, all attributes associated with the equipment are returned. Should the equipment or attributes identified not be defined in the IC configuration, the IC will send a message similar to the negative acknowledgment to a TCO indicating what particular field of the request message was found in error. If the AUDIT request message is found to be supported by the current IC configuration, the IC may will use the configuration entries identified by the 'equipctl.ini' file to recover the current values and will form a response message similar to the TCO message and send it to the MC. The response message format is as follows:

AUDIT

MessageSequenceNumber

15 Equip=EquipmentClass:EquipmentUnitName

Time=YYYYMMDDHHMM

Attribute1=Value1

Attribute2=Value2

20 The Implementation component (IC) reads its configuration files at startup and constructs memory resident database tables and data 'objects' to facilitate rapid access to the configuration information stored in those files.

Among the data read from the configuration files are the records that describe the equipment that the Management Console (MC) application will attempt to control by its commands to the Equipment Controller. The MC will communicate with the Equipment Controller in message with a format similar

5 to:

Equip=EquipmentClass:EquipmentUnitName

Attribute1=Value1

Attribute2=Value2

10

where 'EquipmentClass' and 'EquipmentName' are character string values that occur in the IC configuration files as identifying a piece of modeled equipment. The values of 'Attribute' and 'Value' are also represented as character strings and hence the entire dialog between the MC and IC is through text based messages.

15 The IC configuration files identify one or more pieces of modeled equipment and a set of attributes that the modeled equipment can support. For example, the following section of an 'equipctl.ini' file describes an equipment element known as 'TRANSMITTER:Outbound.' The modeled attributes are identified by the 'EquipModemAttrs' entry and list the values TXF TXR MODT
20 MODR ENCT ENCR DENC SCR PWR CXR as the legitimate attributes of the unit known as 'TRANSMITTER:Outbound.'

[Outbound]

EquipName=Outbound

EquipClass=TRANSMITTER

EquipModelAttrs=ALL TXF TXR MODT MODR ENCT ENCR DENC SCR

5 PWR CXR

EquipAttrSetCmds="" EFDataTxfSetCmd EFDataTxrSetCmd

EFDataModtSetCmd

EFDataModrSetCmd EFDataEnctSetCmd EFDataTxrSetCmd

EFDataDencSetCmd EFDataScrSetCmd EFDataPwrSetCmd

10 EFDataCarrierSetCmd

EquipAttrSetCmdParms="TXF TXR ENCT PWR" "TXF" "ENCR TXR"

"MODT" "MODR" "ENCT" "ENCR TXR" "DENC" "SCR" "PWR"

"CXR"

EquipAttrSetCmdPorts=Serial5

15 EquipAttrSetCmdAddrs="1"

EquipAttrMonConns="" EFDataTxfMon EFDataTxrMon EFDataModtMon

EFDataModrMon EFDataEnctMon EFDataEncrMon EFDataDencMon

EFDataScrMon EFDataPwrMon EFDataCarrierMon

EquipAttrMonConnPorts=Serial5

20 EquipAttrMonConnAddrs="1"

AssociatedEquipment=RECEIVER:Demod1

This configuration entry also associates other configuration entries with the equipment attributes that permit the equipment controller to set (modify) and get (recover) the attribute values from an actual piece of serially attached equipment. The entries in the list of 'EquipAttrSetCmds' refer to entries in the 'serial.ini' file that describe the actual command to be sent. The entries in the 'EquipAttrSetCmdPorts' and 'EquipAttrSetCmdAddrs' describe which serial port the attached equipment is connected to and the address of the attached equipment (in the case that multiple pieces of equipment are attached via the same serial port). Similarly, the 'EquipAttrMonConns' entry refer to configuration entries in the 'monitor.ini' file that describe the mechanism by which the attribute is recovered from the attached equipment and the 'EquipAttrMonConnPorts' and 'EquipAttrMonConnAddrs' describe the serial ports and addresses used for data recovery.

Hence the IC is in not actually aware of the semantics of the data values it is 'setting' or 'getting' and the mapping between the equipment and equipment attributes that the MC believes it is controlling is completely defined by the equipment controller configuration files and not equipment controller software.

The MC and IC communicate via the text format generally described above. All communication is initiated by the MC. Three request packets are currently defined: 1) a request to modify the attributes of a particular piece of equipment at a particular time in the future, 2) a request to cancel the request to modify the attributes of a particular piece of equipment, and 3) a request to return the current values of the attributes of a particular piece of equipment.

Each request is normally responded to with a complementary message. In some cases, however, no response message purposely generated in order to communicate a negative response.

The request to modify the attributes of a particular piece of equipment is known as a Transmission Change Order (TCO). The format of a TCO is as follows:

TCO

MessageSequenceNumber

10 Equip=EquipmentClass:EquipmentUnitName

Time=YYYYMMDDHHMM

Attribute1=Value1

Attribute2=Value2

15 When the IC receives a TCO it validates the request. The request validation includes confirming that the requested change time has not already past and that the IC configuration supports the requested modifications. The IC refers to its memory resident database of configuration data to validate request. First the IC insures that the requested equipment is identified in the configuration. It then insures, by tracing the attributes named in the request through the configuration to the commands that must be issued to insure that sufficient configuration information is present to form the required commands. Finally it checks to see if the equipment is currently responding to commands.

If an error is detected such that the request cannot be supported by the configuration, a response is returned to the MC identifying the offending request data. For example, if a request contained an equipment identification that did not exactly match an entry in the 'equipctl.ini' file or if an attribute name did not exactly match one of the legitimate attributes named in the 'equipctl.ini' file, a response would be sent indicating why the TCO was invalid and implicitly indicating that the request would not be implemented. Further, if a legitimate attribute is named, but the equipment controller finds that either no serial command is referenced or that the referenced serial command is not configured, the IC will also send a similar response indicating why the request cannot be implemented. Validation of the parameter values may also be accomplished in a similar technique.

If the request is otherwise correct, but the equipment is currently not responding to serial commands, no response is purposely generated, indicating that no problem was detected in the request but that the since no acknowledgment was sent, the request will not be implemented at the specified time.

Else an acknowledgment is returned to the MC indicating that unless otherwise instructed, the IC will perform the requested configuration change at the requested time.

The request to cancel the modification of the attributes of a particular piece of equipment is known as a Abort Message (ABRT). The format of an ABRT is as follows:

ABRT

MessageSequenceNumber

Equip=EquipmentClass:EquipmentUnitName

- 5 The IC will remove the outstanding command set to be issued to the specified equipment if any command is queued and will send an acknowledgment to the MC indicating it has done so. If, at the time of receipt, no command is outstanding, the IC will respond with a message indicating that no command was found.
- 10 Figure 13 depicts a flow chart of a transmission plan execution. Initially, the system may have an unscheduled transmission (1302). The transmission plan may be assigned an execution time (1304). The transmission plan may be propagated to the network to place the plan onto a pending status (1306). After all of the TCO's required to implement the transmission plan
- 15 have acknowledged the command, the transmission plan is ready for execution (1308). At the transmission plan execution time (1310) the plan began the start sequence. After the MC confirms that all TCO's have been confirmed, *e.g.*, so that the MC does not issue an abort command, the transmission plan goes active (1312).
- 20 The system then begins normal operation on the new transmission plan and the system begins collecting data again on link usage (1316). Special transmission plans, *e.g.*, transmission plans that are not recurring, are not re-scheduled (1318).

Figure 14 depicts a bandwidth allocation request. This control loop may execute at the MC. The system may receive a request for bandwidth 1402 from the Bandwidth administrator or an IC. The request may be an unscheduled network event 1404. The request for bandwidth is decoded and scheduled for execution 1406. The execution schedule may be for immediate execution or for a scheduled deployment. The appropriate TCO may be sent from the MC to the appropriate IC to propagate the transmission plan and to put the plan into the ready state 1408. The transmission plan then waits for its execution time. When the transmission plan execution time arrives (1410) the MC confirms that the TCO's were confirmed by the ICs. If the TCO's were confirmed, the plan goes active (1412) at the predetermined time. the system has thereby fulfilled (1414) the bandwidth request.

The IC may implement a control loop similar to that shown and described above. The IC may confirm that a channel is available within the present transmission plan 1406 and immediately execute the new transmission pan 1408, 1410 and 1412. The IC may then notify the MC 1402 of the unscheduled 1404 transmission plan. The MC may then proceed as described above to propagate and deploy the new plan.

Figure 5 depicts the inter-process communication between the MC 502 and ICs (506) and 542. MC commands are sent via the UDP/IP link 504 from the control component 503 to the equipment control component 514. The equipment controller 514 then maps the generic network commands from the MC to specific commands (discussed above) for output (512) to the managed

equipment (510). The equipment controller (514) may lose the command event (524). The IC may also denote the command event on the local display 530.

The system may receive alarm and other network messages that may effect the network management display 518 via the TCP/IP connection 516.

5 Equipment controller 514 may connect to the display controller 518 when the equipment controller 514 receives an alarm condition from the network equipment (510,520) via command links (512, 522). The event logger (534) may receive network audits and network events from the IC 506 equipment controller (514) via UDP/IP link 532. As provided above, each of the
10 communication processes on Figure 5 may be interpret or poll driven.

The IC may also denote the command event on the local display 530.

The system may receive alarm and other network messages that may effect the network management display 518 via the TCP/IP connection (516). Equipment controller (514) may connect to the display controller (518) when
15 the equipment controller 514 receives an alarm condition from the network equipment (510,520) via command links (512, 522). The event logger (534) may receive network audits and network events from the IC 506 equipment controller (514) via UDP/IP link (532). As provided above, each of the communication processes on Figure 5 may be interrupt or poll driven.

20 Other embodiments and uses of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. The specification and examples should be

considered exemplary only. The scope of the invention is only limited by the claims appended hereto.

Therefore we claim:

1. A system for controlling a network of communication terminal comprising:

5 a management component;

an implementation component, said implementation component in communication with said management component to receive at least one transmission plan, said transmission plan containing a scheduled implementation time, said implementation component receiving said
10 transmission plan, decoding an implementation time for said transmission plan and outputting command to network component at said implementation time to implement said transmission plan.

2. A method for managing a communication network with an adaptive
15 transmission plan comprising:

analyzing network bandwidth allocation over a predetermined period of time;

determining a transmission plan to accommodate, at least in part, the results of said analysis of said network bandwidth allocation;

20 deploying said transmission plan to a plurality of network component to implement said transmission plan; and

analyzing network bandwidth allocation short falls over a predetermined period of time to identify a transmission plan that accommodates bandwidth demands.

- 5 3. A method for facilitating network management in a multiple vender network comprising:

receiving a generic network command at an implement component;

decoding said generic network command;

- 10 translating said decoded generic network command to specific commands for a particular device through a text based file that contains text strings of specific device commands; and

outputting said translated commands to said particular network device.

Figure 1
STAR TOPOLOGY

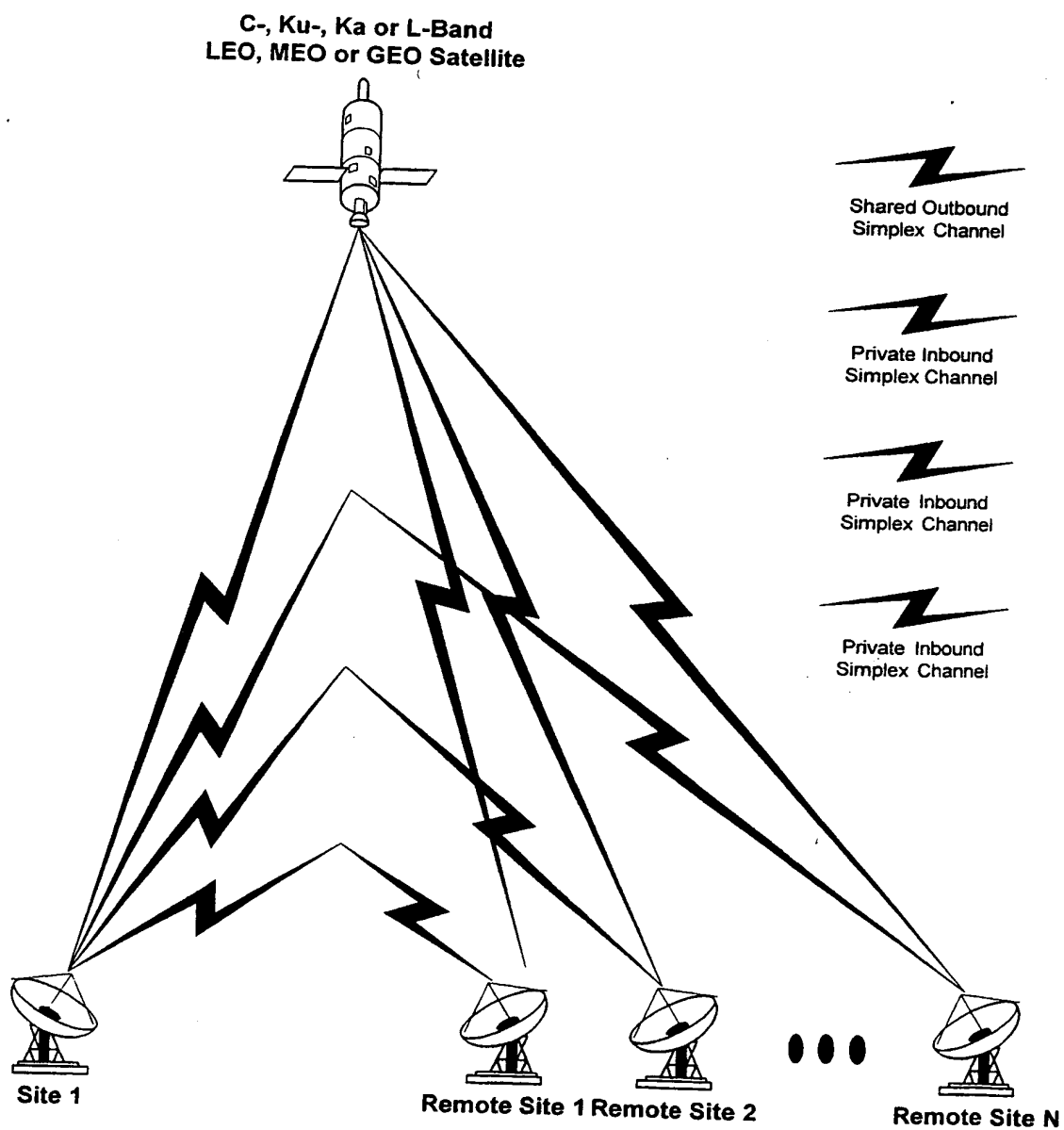


Figure 2
MESH TOPOLOGY

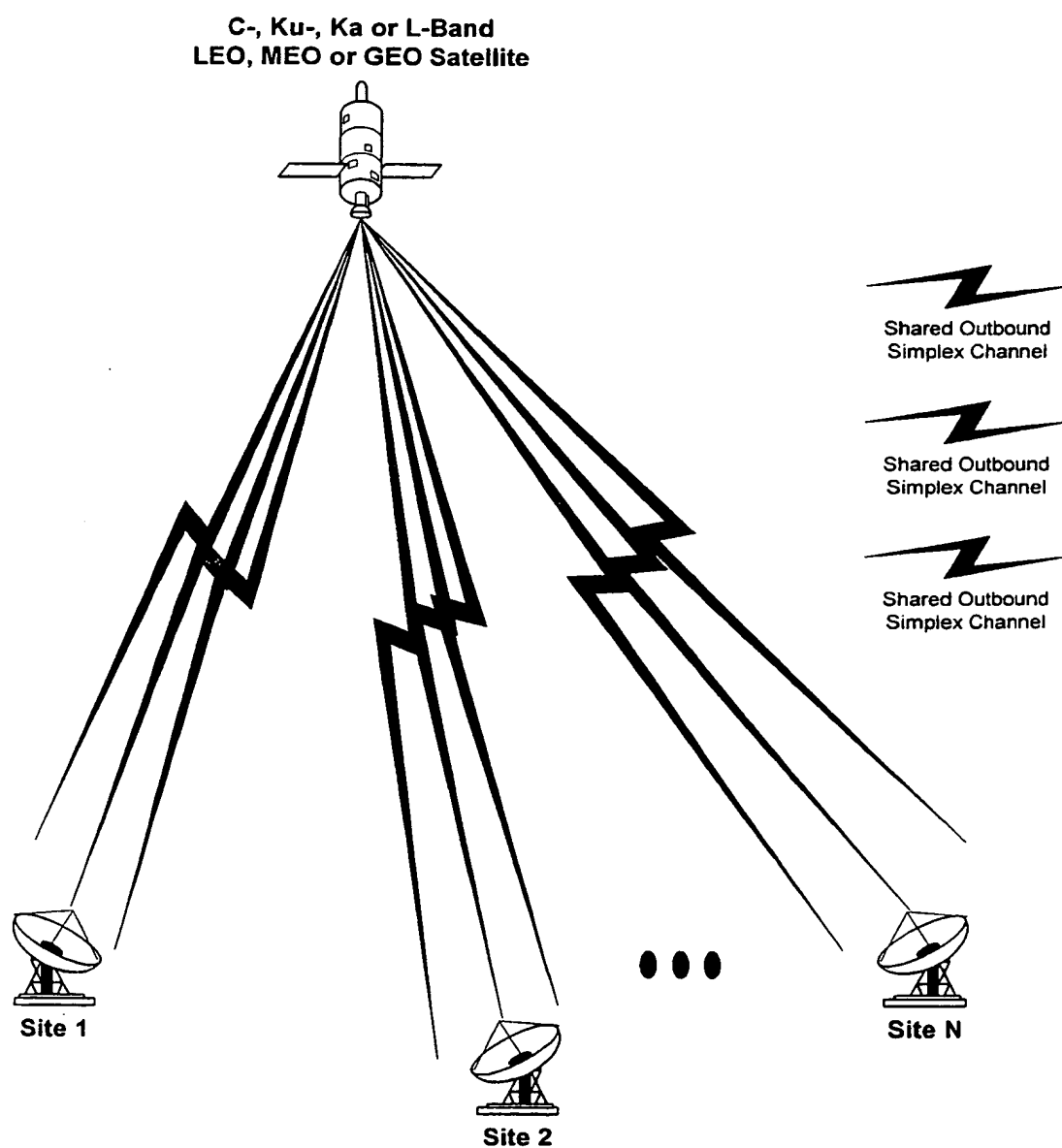


Figure 3
TRANSMISSION EQUIPMENT MODEL

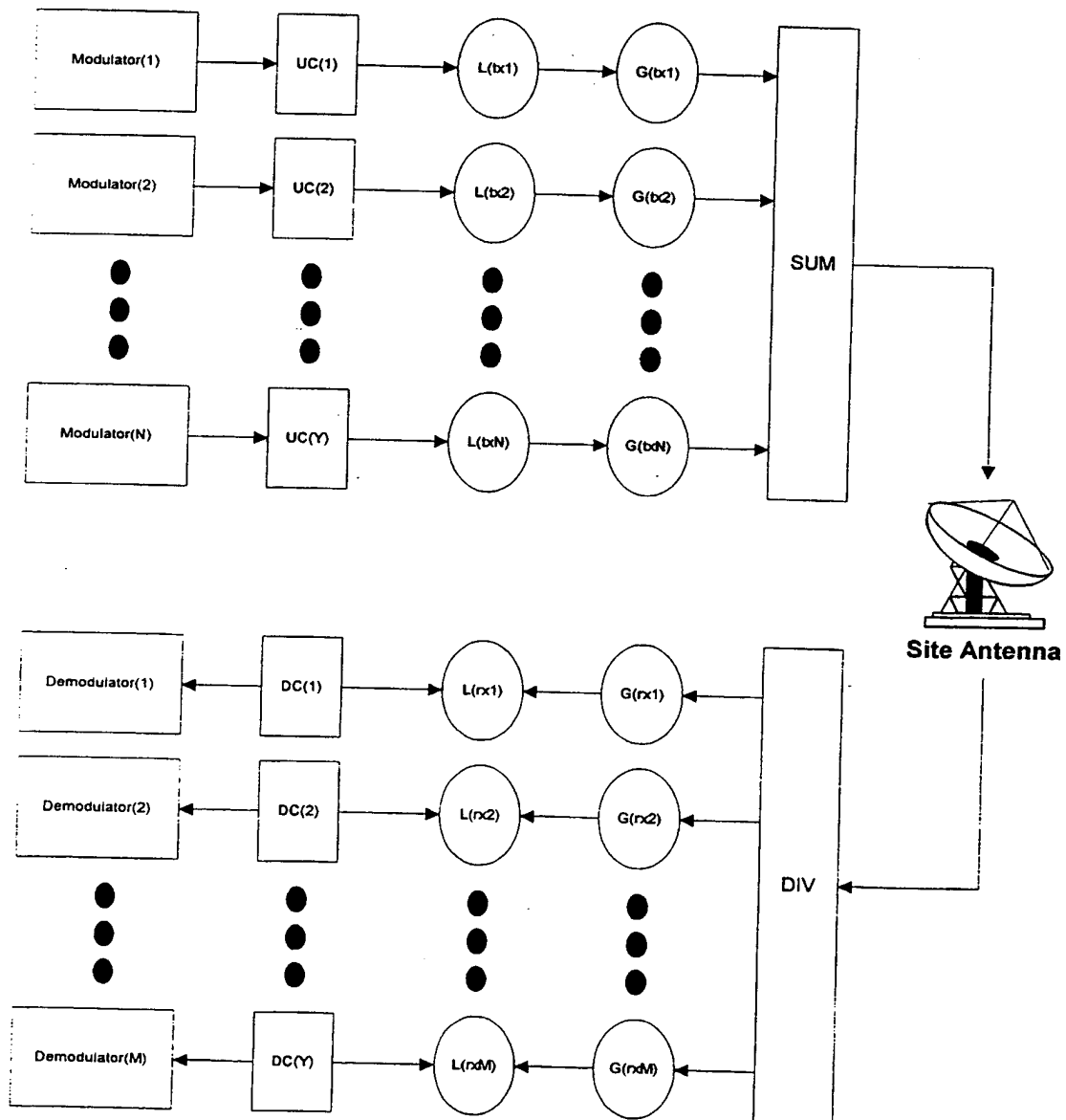


Figure 4
NMS MANAGED EQUIPMENT

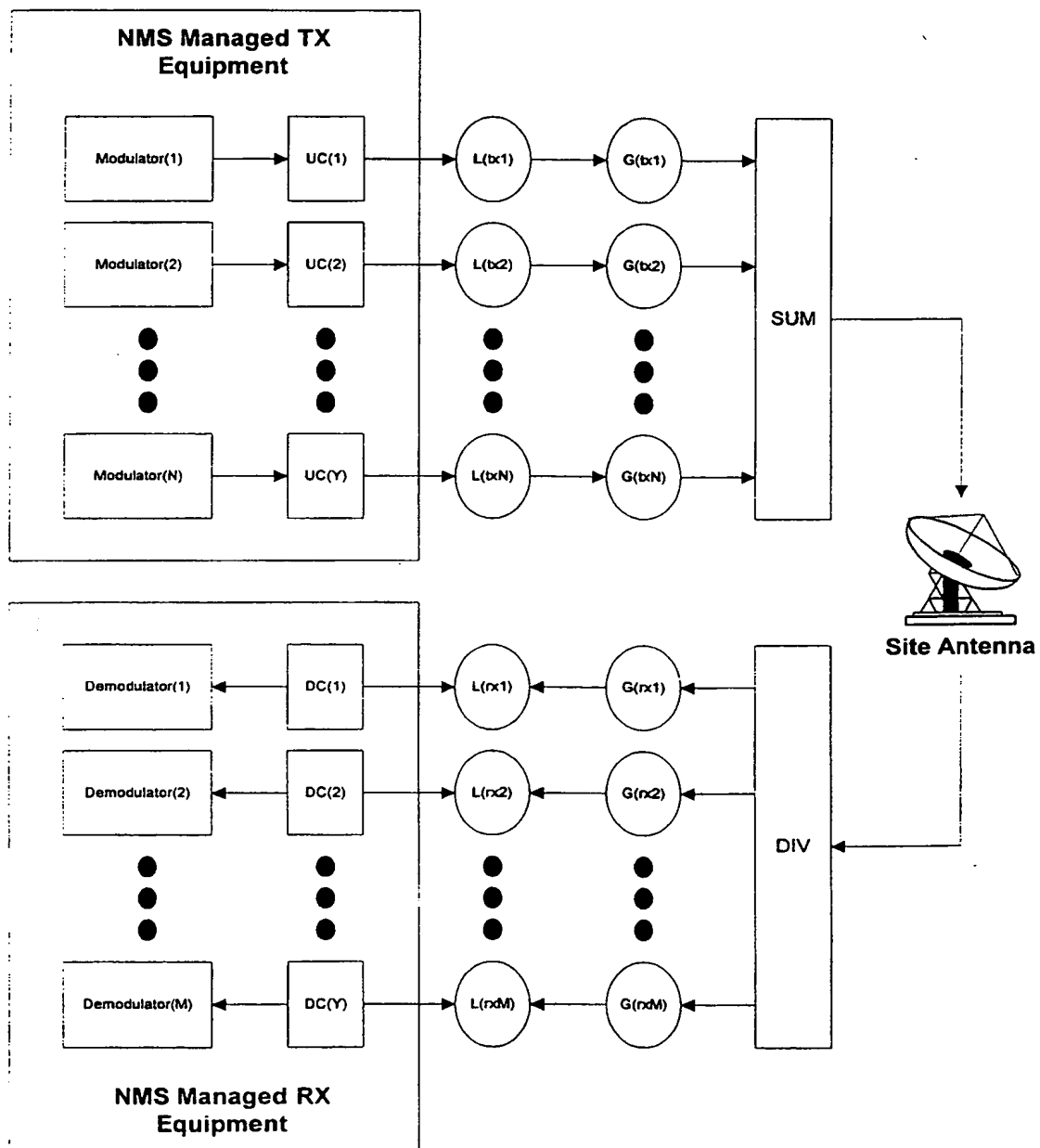


Figure 5
DISTRIBUTED
SOFTWARE COMPONENTS

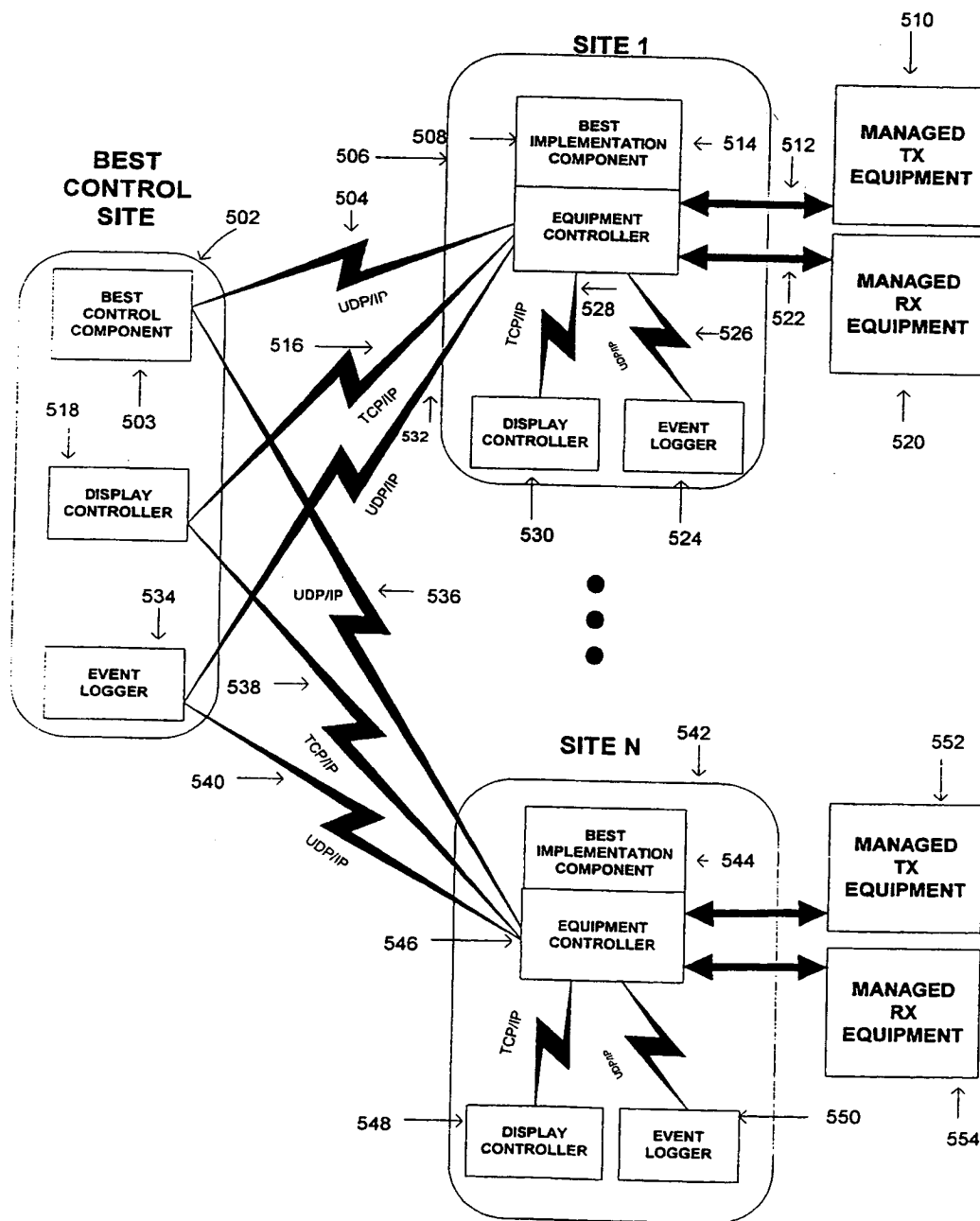


Figure 6i

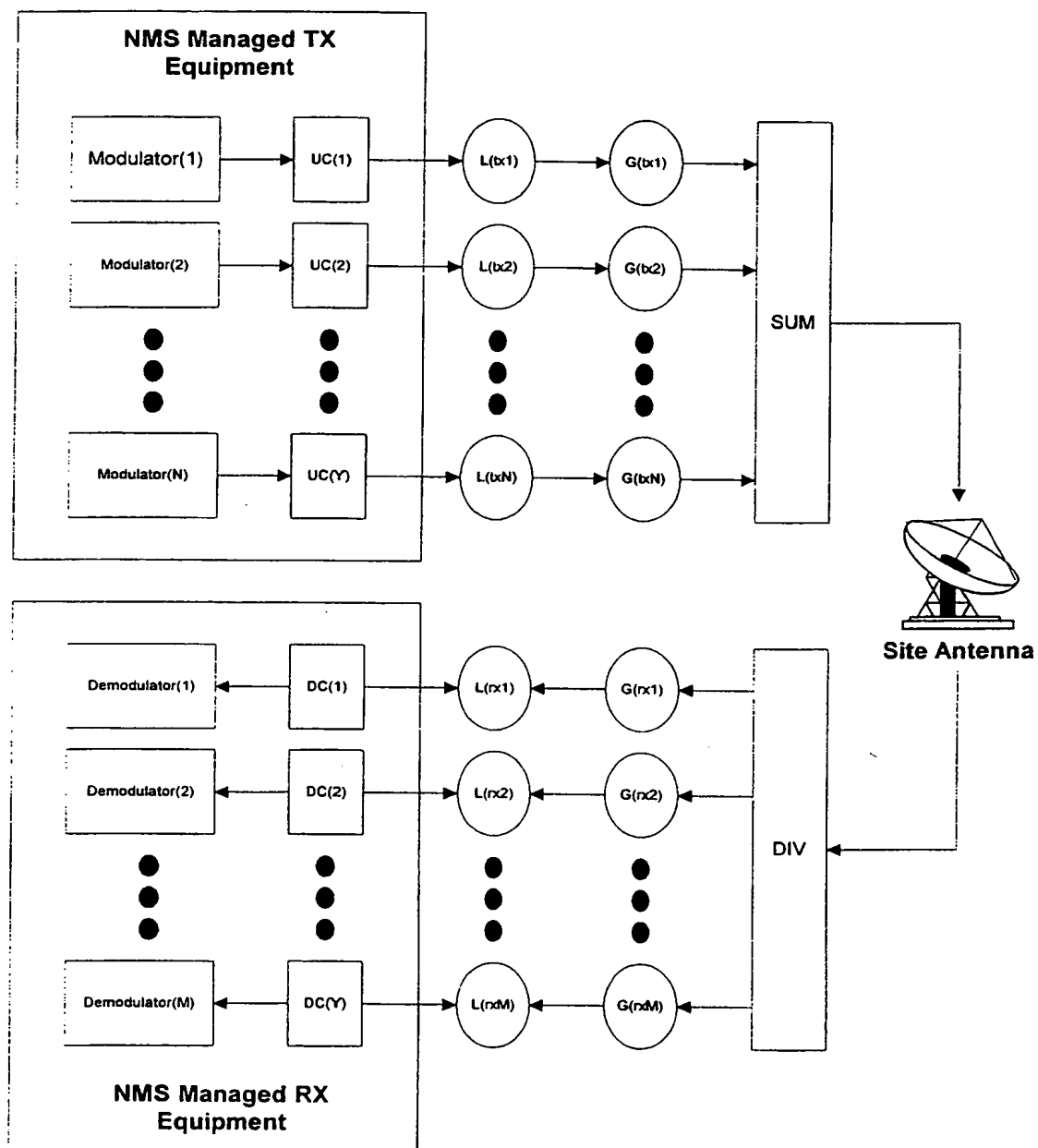
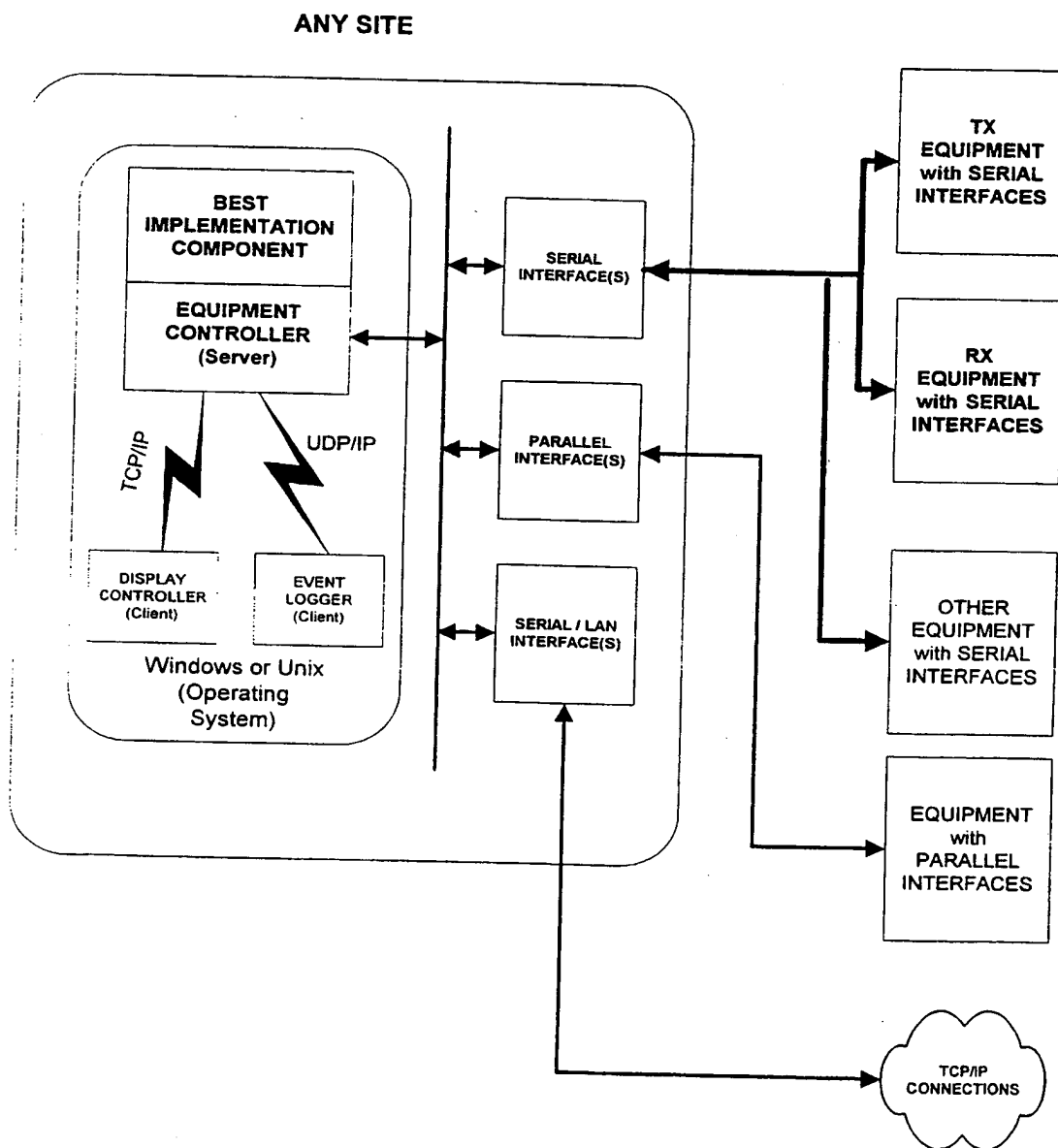
NMS MANAGED EQUIPMENT

Figure 7.

EQUIPMENT CONTROLLER ENVIRONMENT

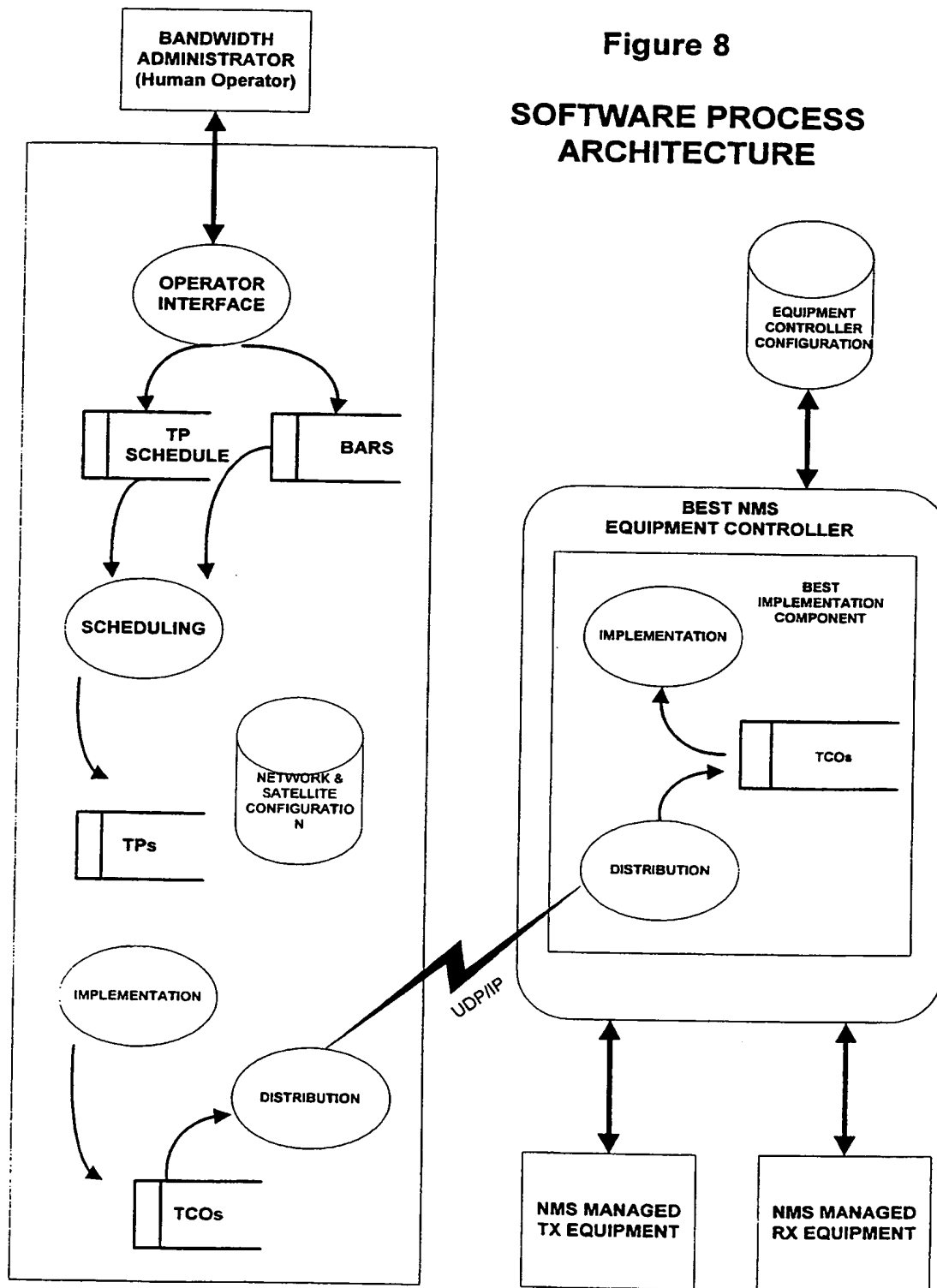


Figure 9
HARDWARE CONFIGURATION
INFORMATION FLOW

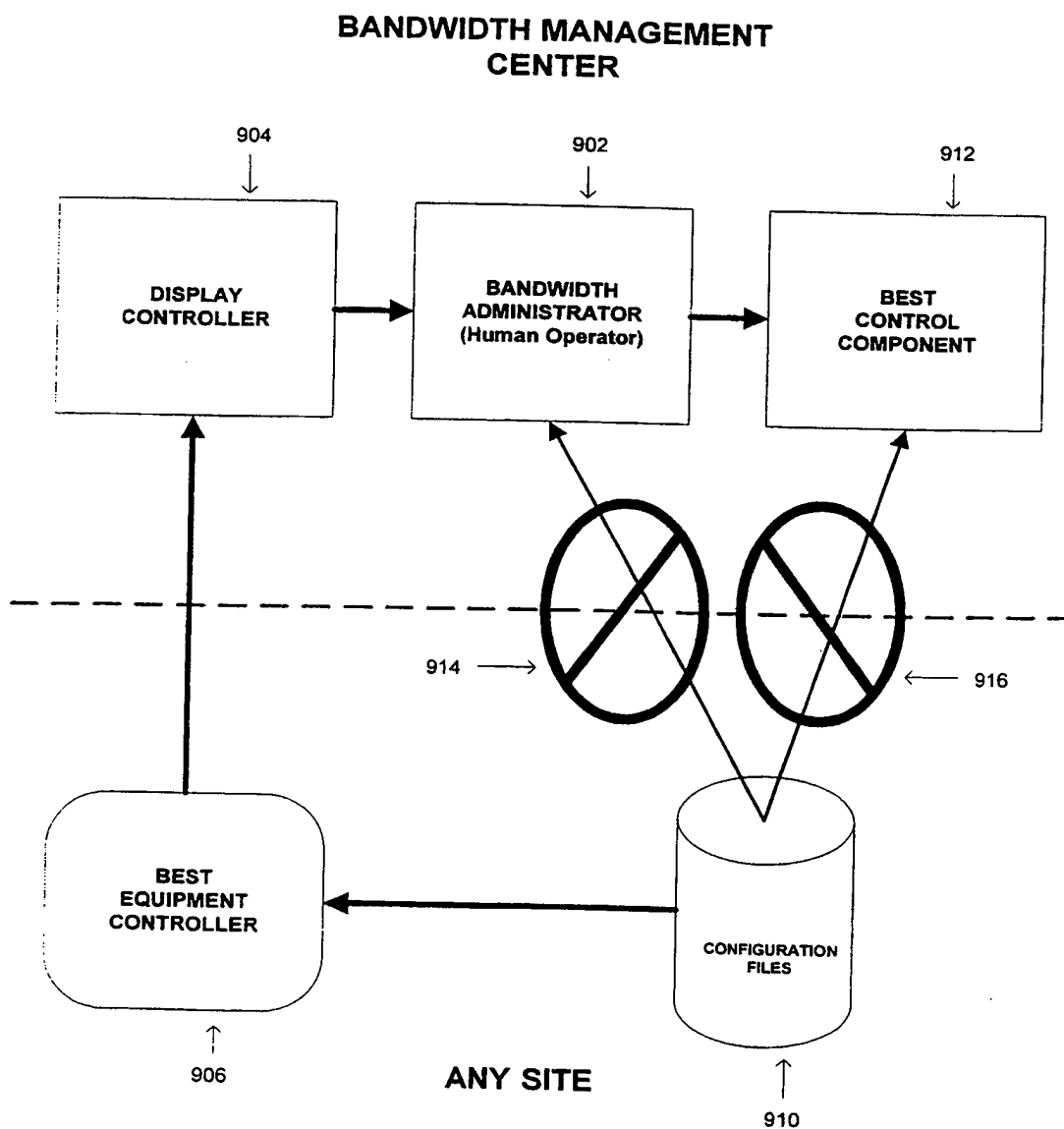


Figure 10.

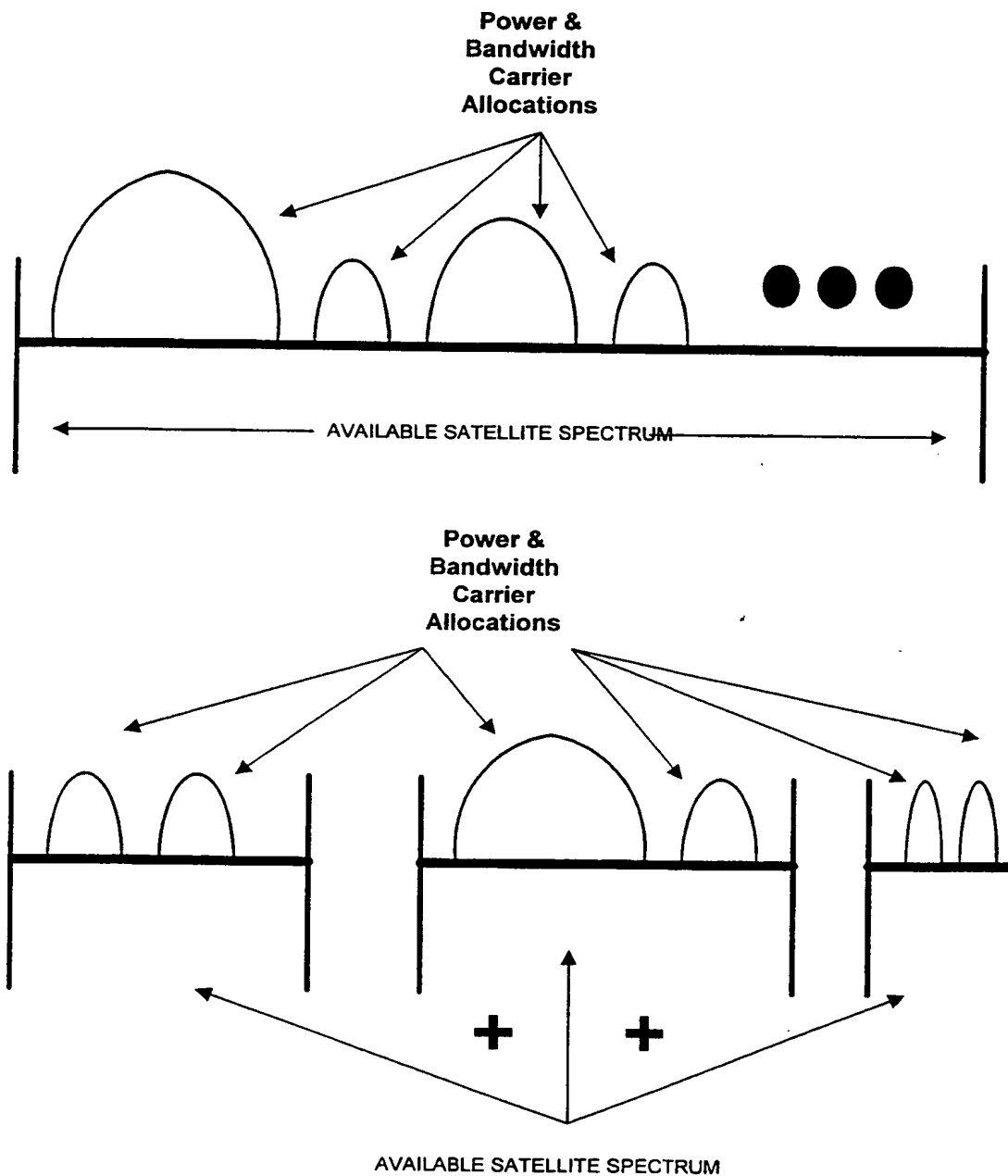
**TRANSMISSION PLAN
CONCEPTS**

Figure 11.

TRANSMISSION PLAN SCHEDULE

	Time 0	Time 0 + 6 hours	Time 0 + 12 hours	Time 0 + 18 hours
Monday	Transmission Plan #1	Transmission Plan #2	Transmission Plan #3	Transmission Plan #4
Tuesday	Transmission Plan #5	Transmission Plan #6	Transmission Plan #7	Transmission Plan #8
Wednesday	Transmission Plan #9	Transmission Plan #10	Transmission Plan #11	Transmission Plan #12
Thursday	Transmission Plan #13	Transmission Plan #14	Transmission Plan #15	Transmission Plan #16
Friday	Transmission Plan #17	Transmission Plan #18	Transmission Plan #19	Transmission Plan #20
Saturday	Transmission Plan #21	Transmission Plan #22	Transmission Plan #23	Transmission Plan #24
Sunday	Transmission Plan #25	Transmission Plan #26	Transmission Plan #27	Transmission Plan #28

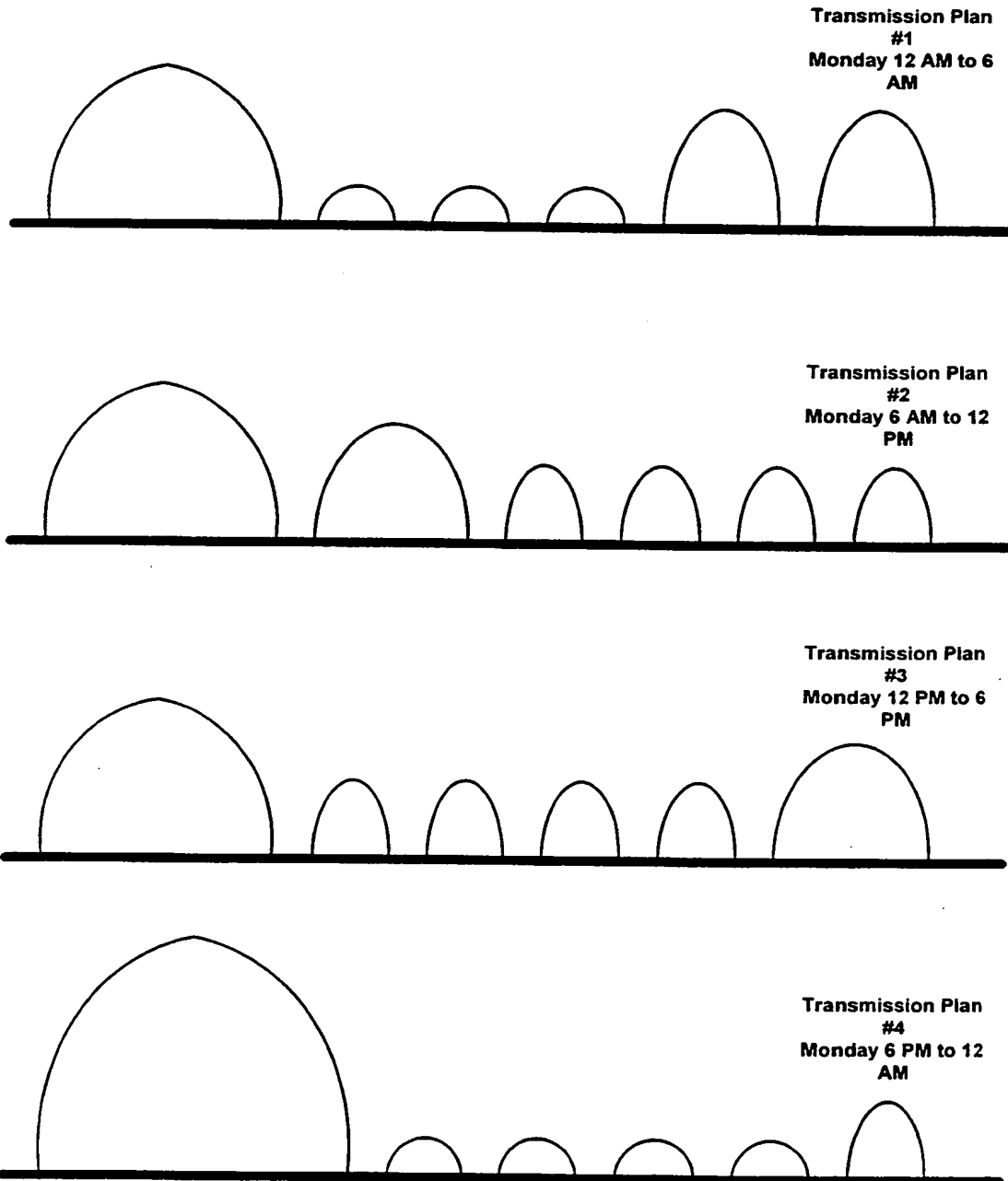
Figure 12.**MONDAY TRANSMISSION PLANS**

Figure 13

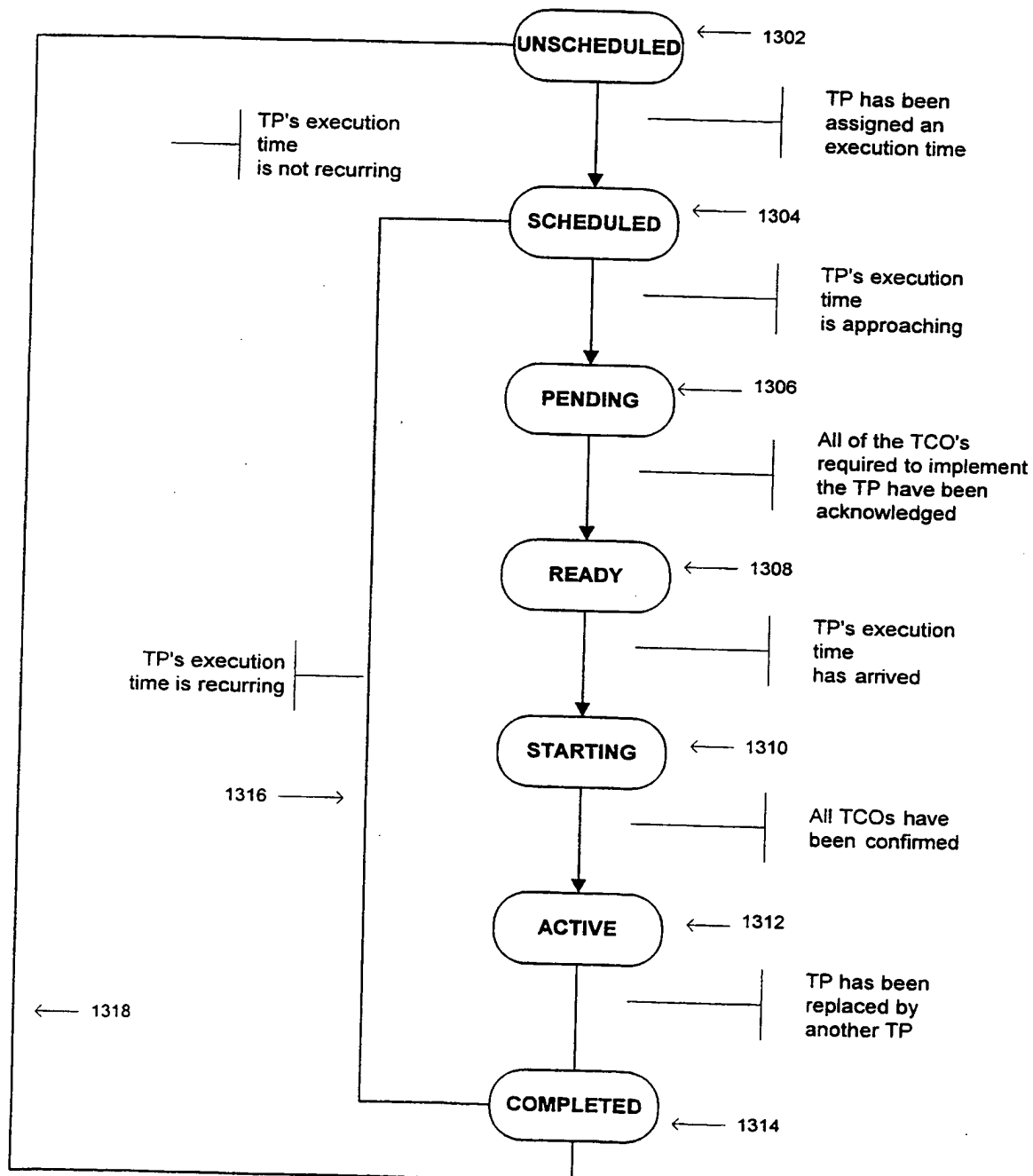
TRANSMISSION PLAN
EXECUTION

Figure 14

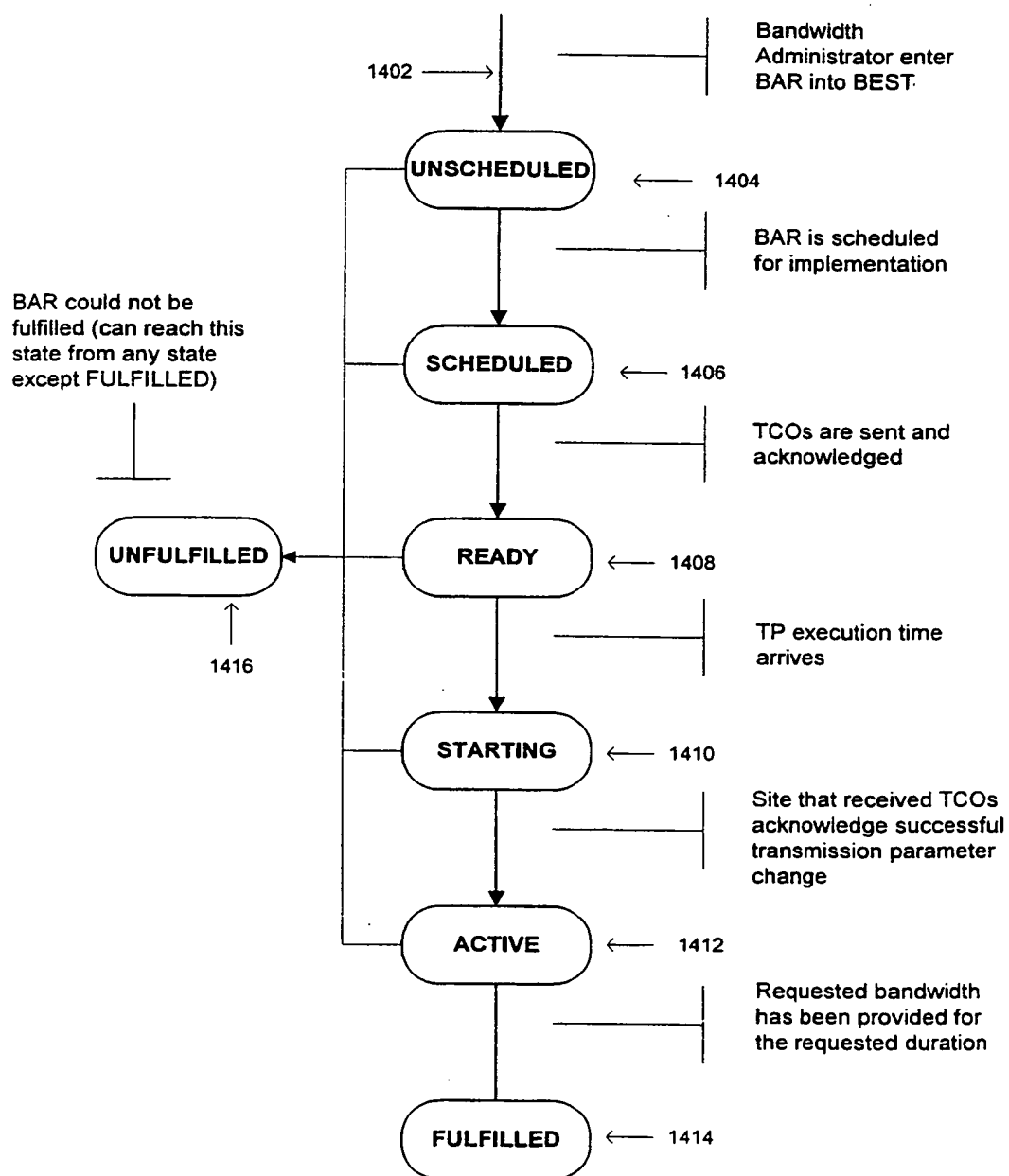
**BANDWIDTH ALLOCATION
REQUEST EXECUTION**

Figure 15
UDP DATAGRAM FORMAT

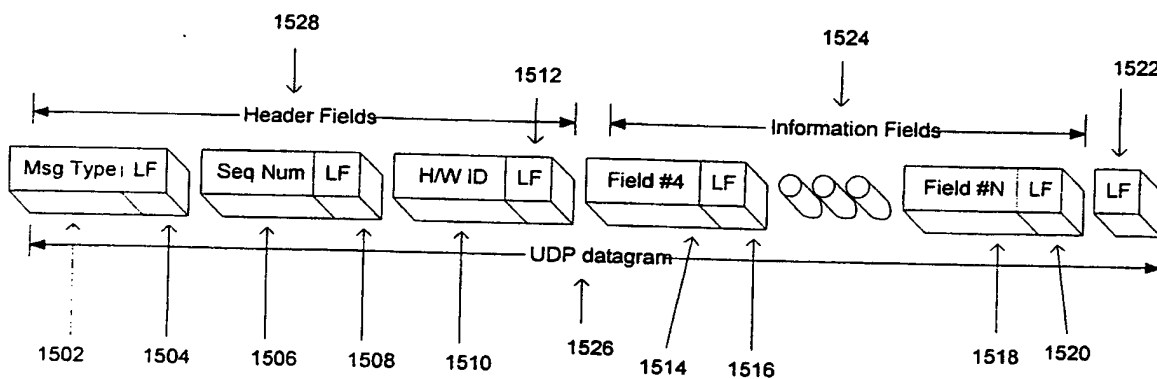


Figure 16

REQUEST/COMMAND FLOW

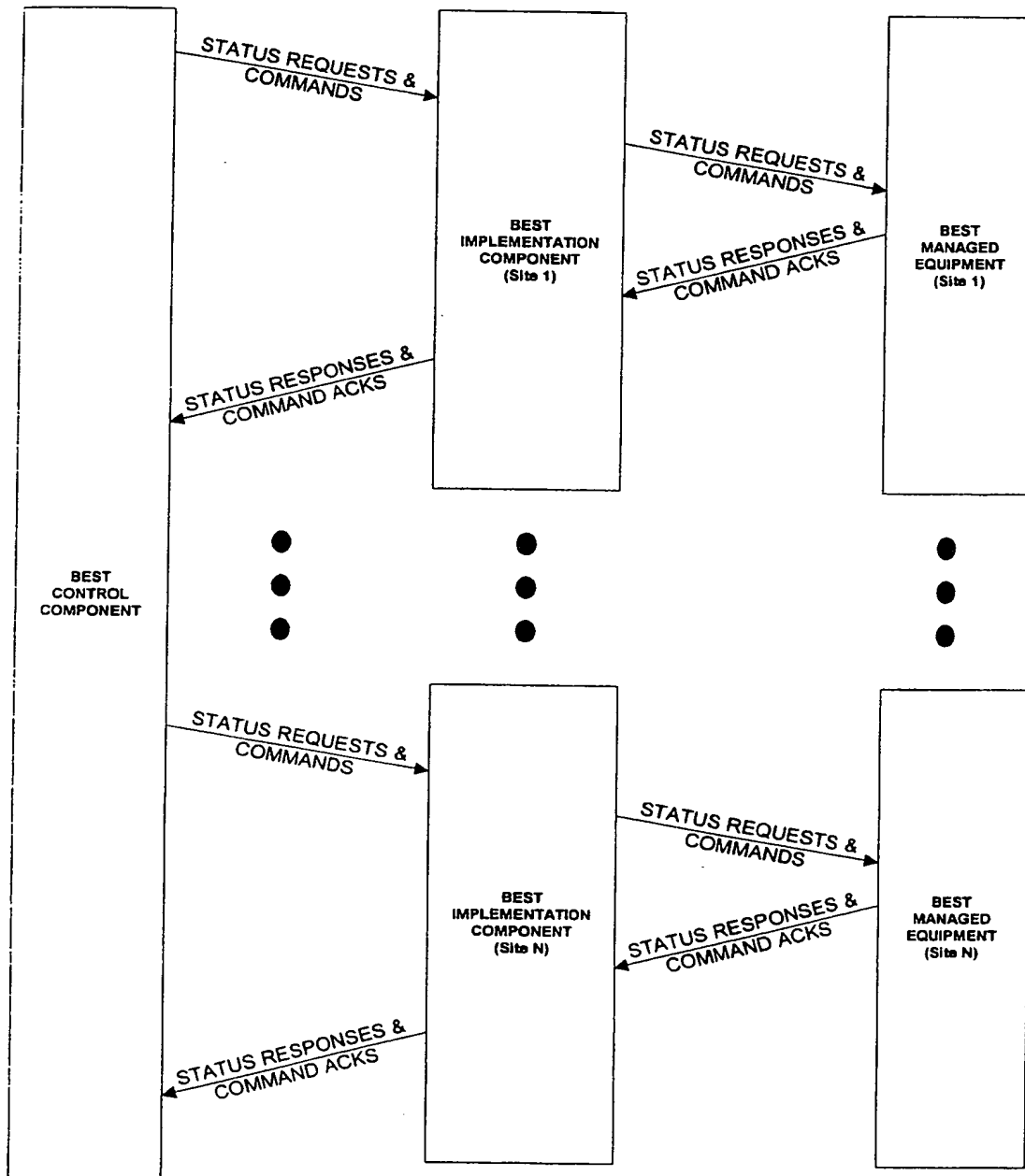


Figure 17

BASIC OPERATION

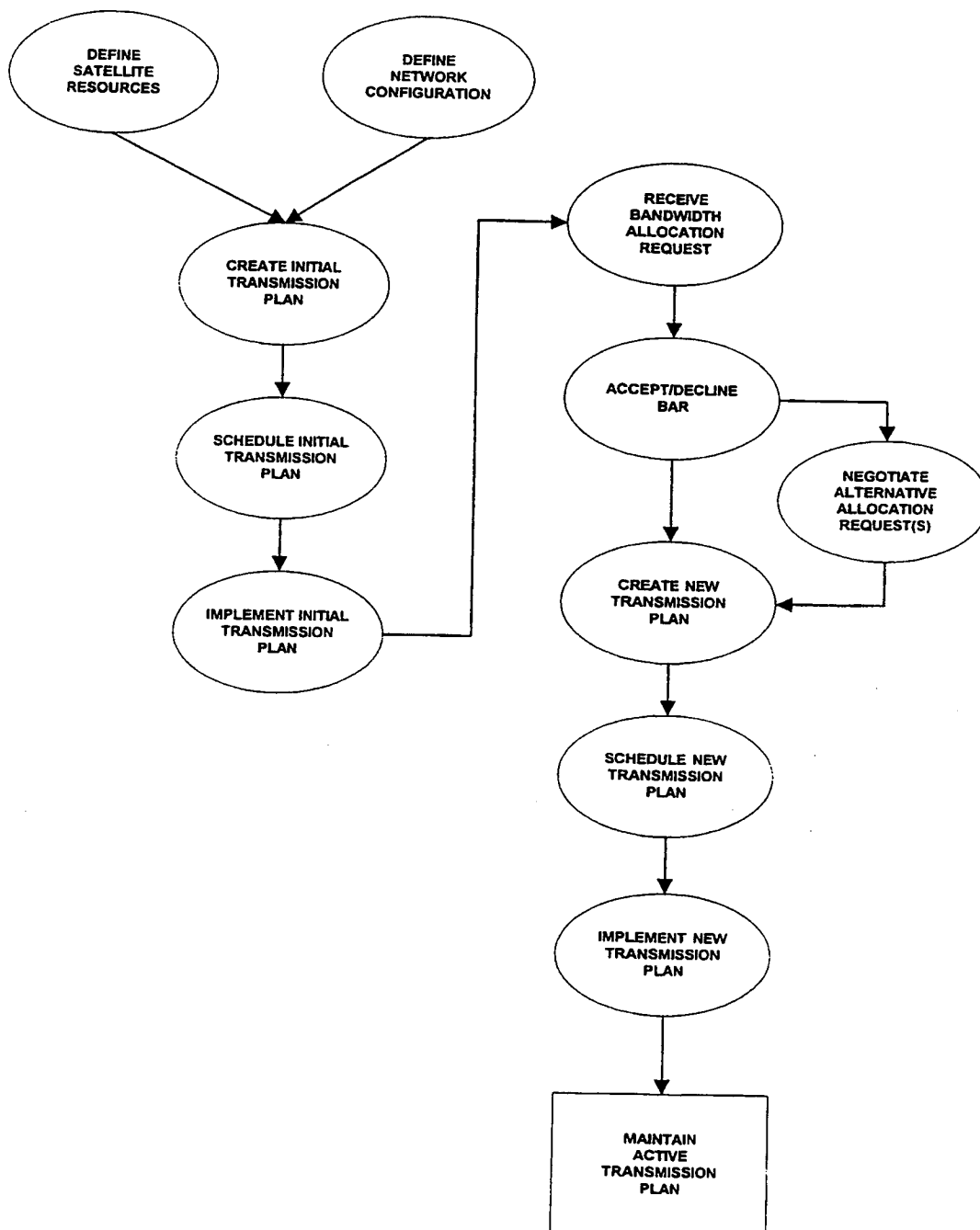
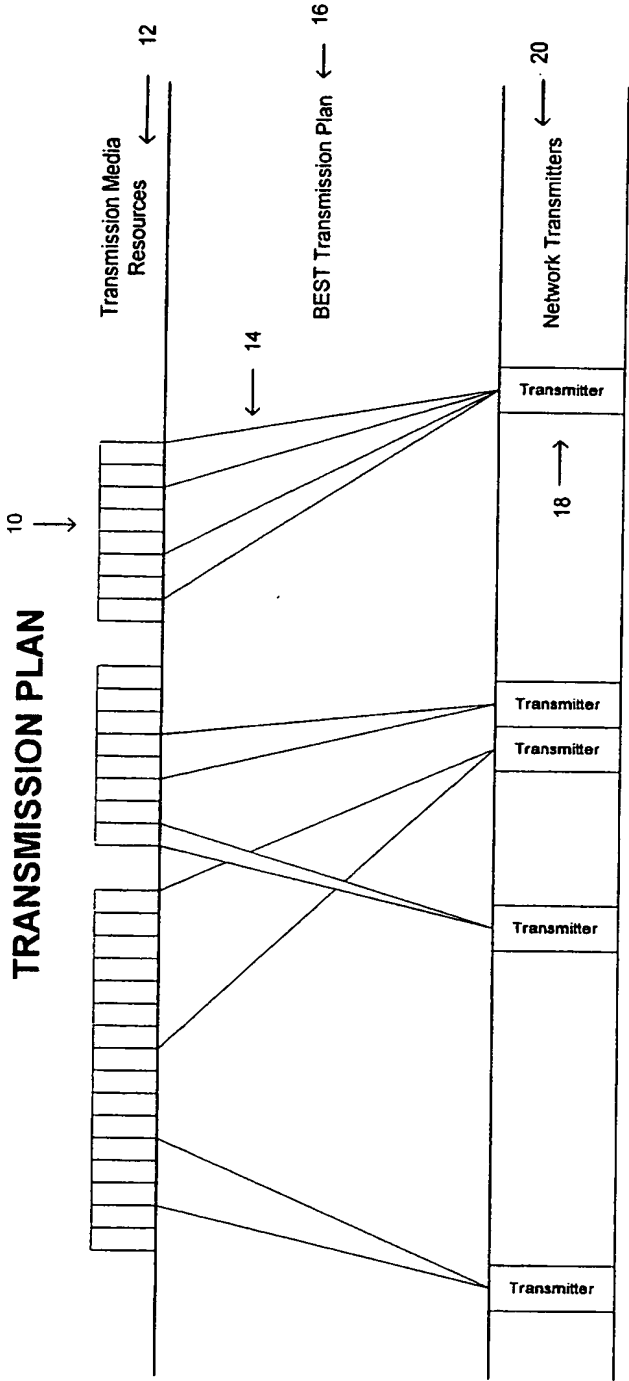


Figure 18.



A BEST Transmission Plan allocates the transmission media resources among the transmitters in a network.

Only transmitters are specified in a BEST Transmission Plan because only transmitters use transmission media resources.

The BMC automatically configures network receivers based on the transmitter the receiver is receiving.

The BMC implements a BEST Transmission Plan by sending commands to the BICs controlling the transmitters and receivers in a network.

Multiple BEST Transmission Plans can be defined.

The BMC maintains a schedule of BEST Transmission Plan implementations.

Figure 19

CONCEPT DIAGRAM

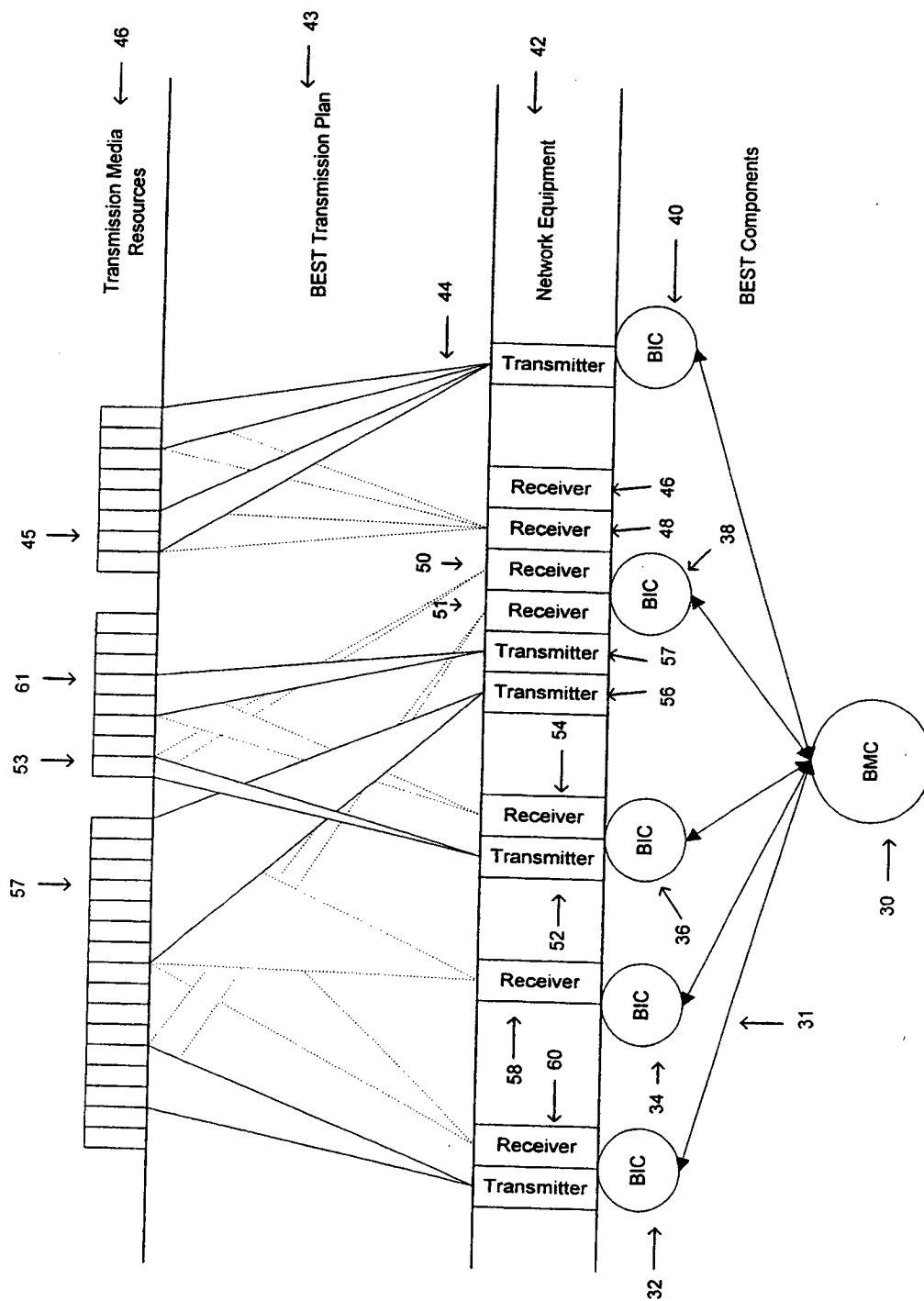


Figure 20

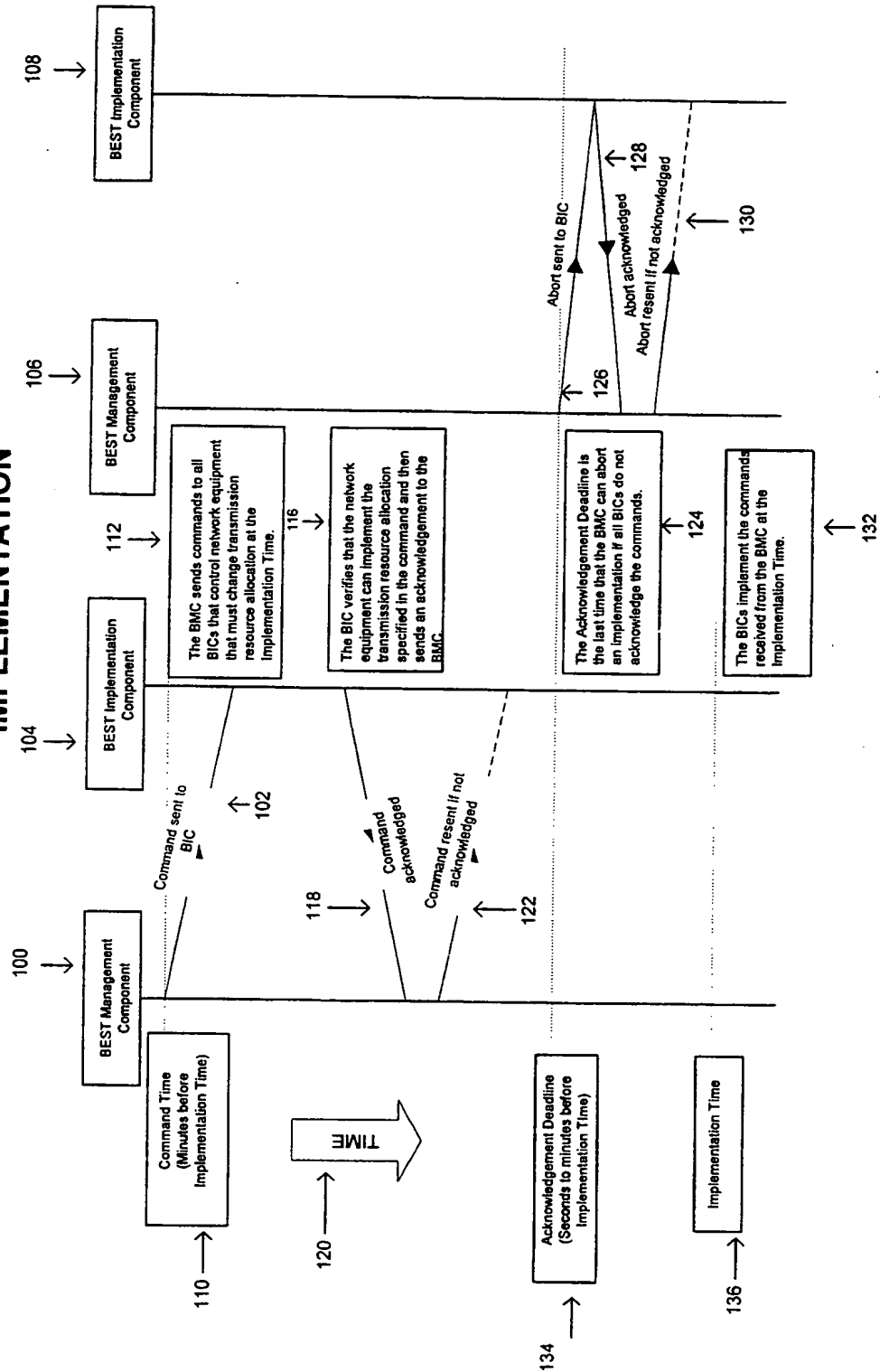
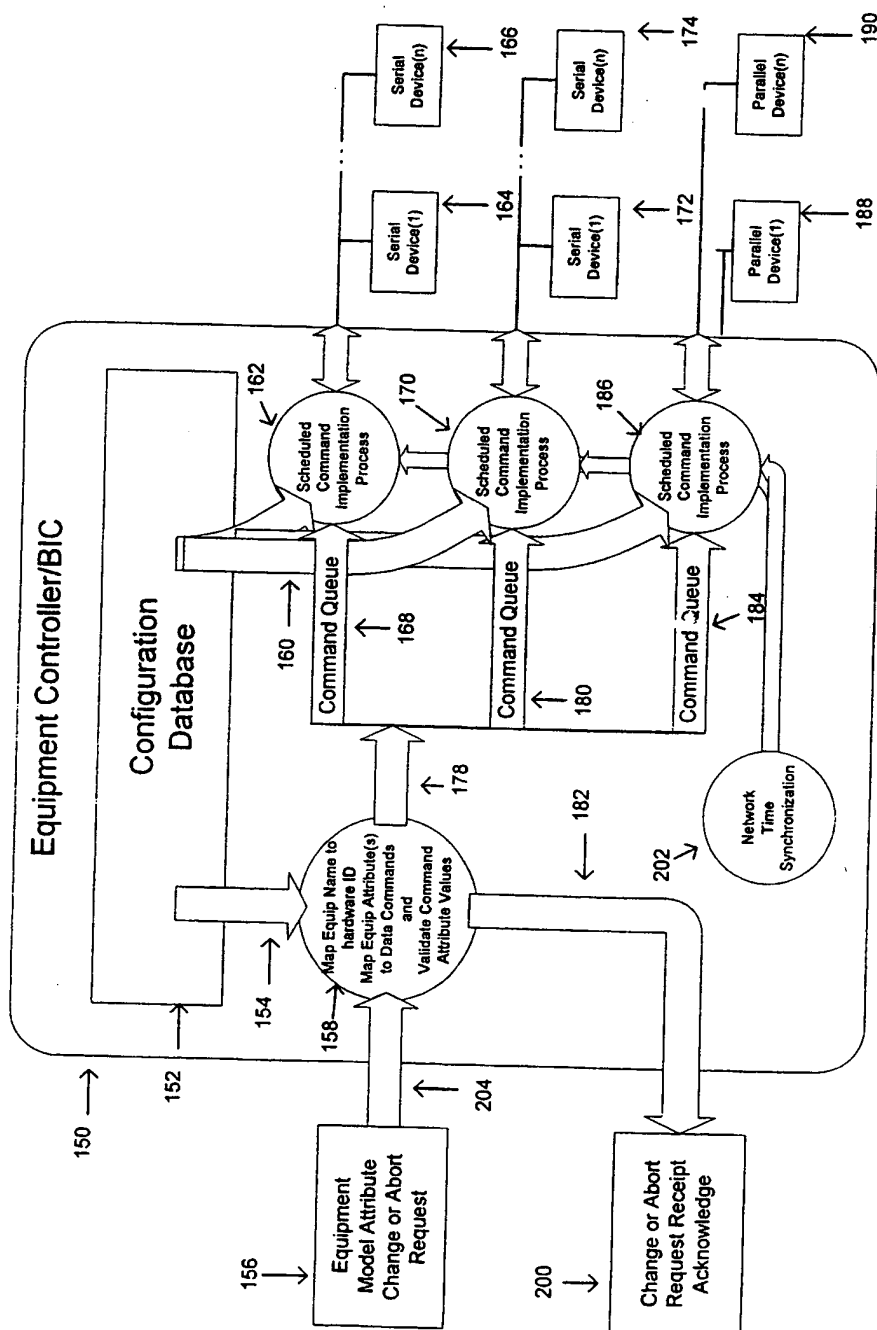
TRANSMISSION PLAN
IMPLEMENTATION

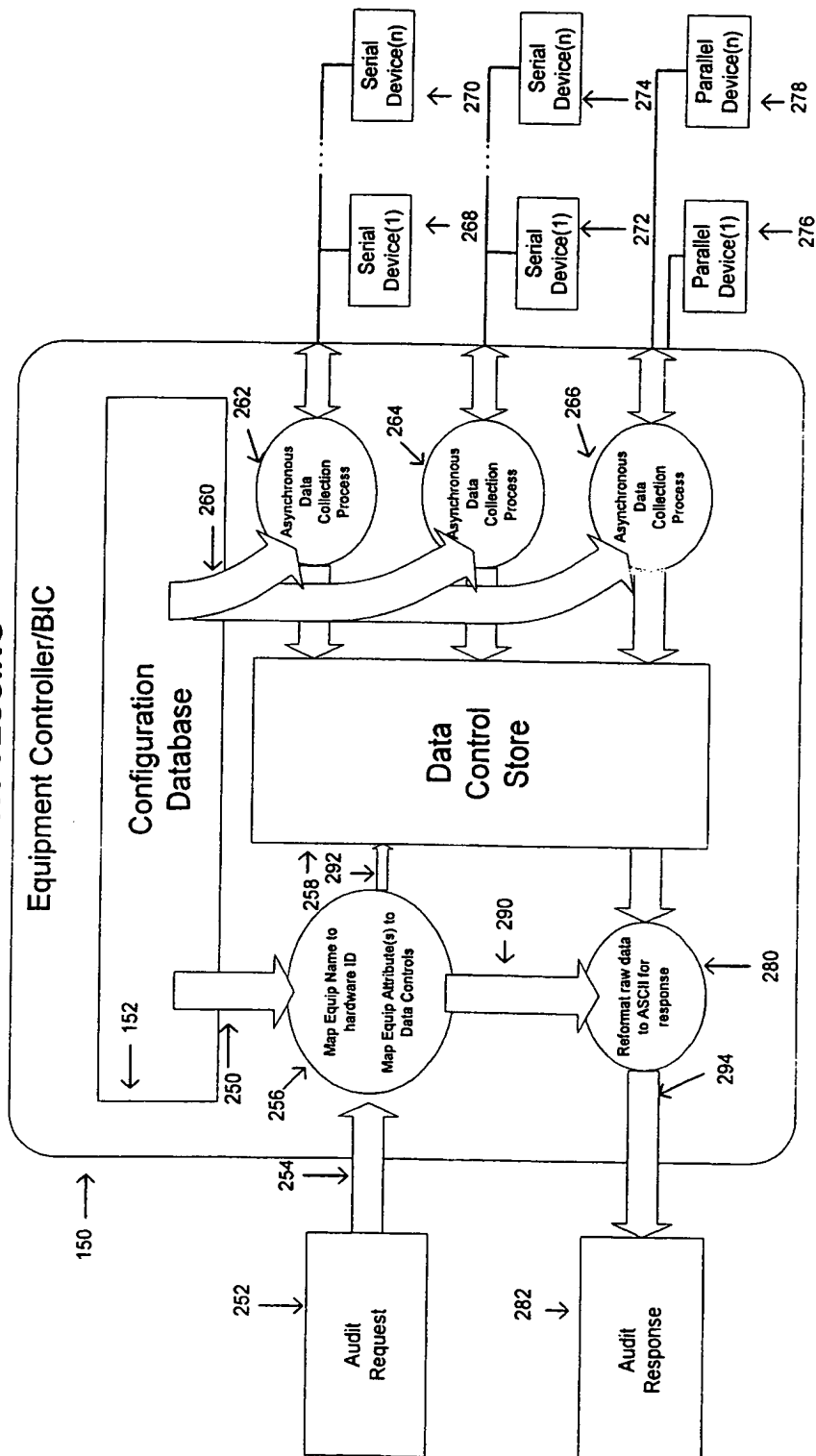
Figure 21
NETWORK COMMAND
PROCESSING



EQC Command Processing.vsd 4/6/99

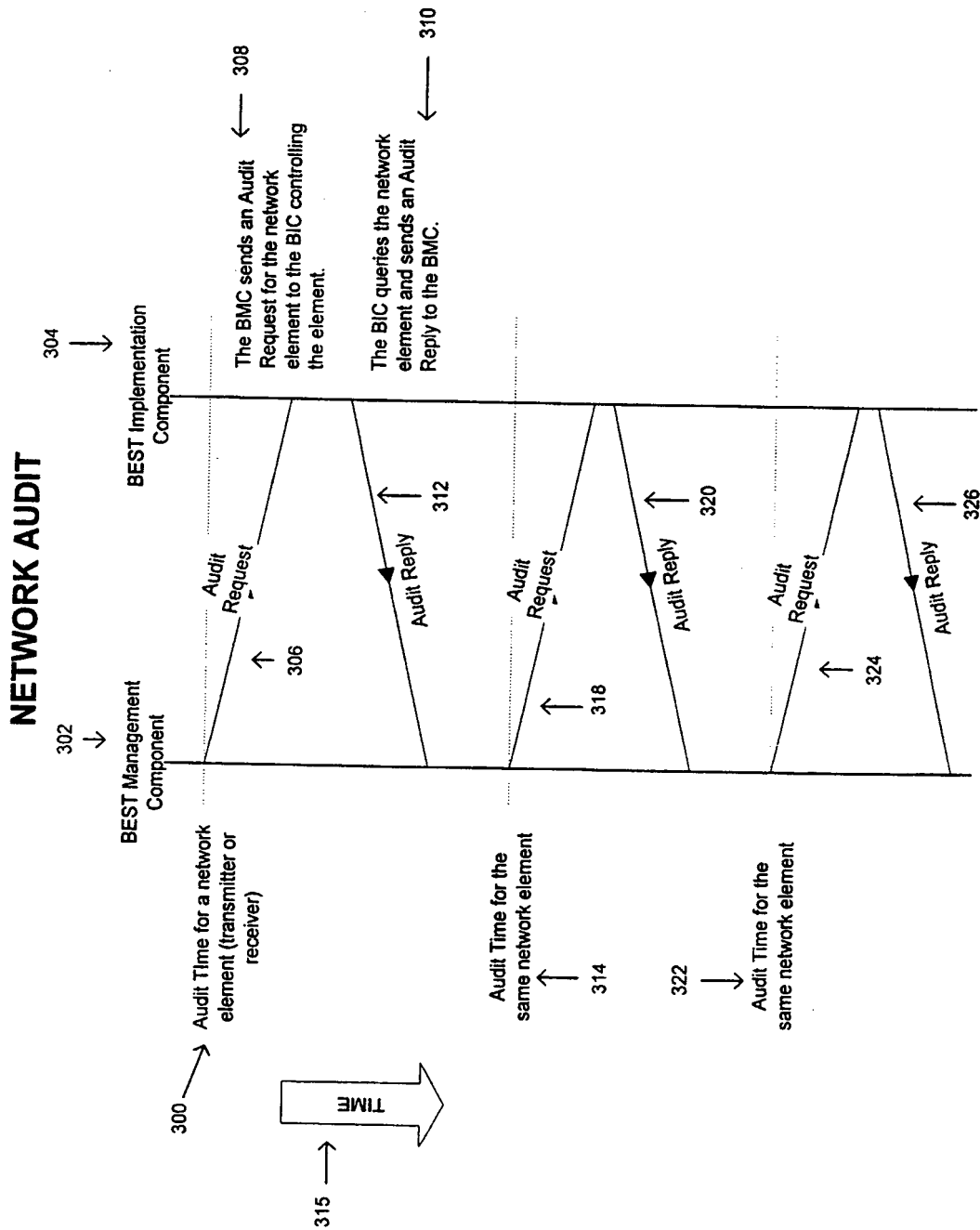
Figure 22

NETWORK AUDIT PROCESSING



EQC Audit Processing.vsd 4/6/99

Figure 23



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/01317

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : H04B 7/00; H04J 1/16

US CL : 370/252, 319, 468

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 370/252, 254, 255, 315, 319, 341, 468

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,689,568 A (LABORDE) 18 November 1997, col. 1, line 45 to col. 2, line 15.	1-3
A	US 5,533,023 A (OHLSON et al) 02 July 1996, abstract.	1-3
A	US 5,592,470 A (RUDRAPATNA et al) 07 January 1997, abstract.	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
B earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 28 MARCH 1999	Date of mailing of the international search report 03 MAY 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer RICKY QUOC NGO <i>Joni Hill</i> Telephone No. (703) 305-4798

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8/28/07